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**Cover illustration:** Males (lines 1 & 3) and females (lines 2 & 4) of two closely related species in each of three genera of neotropical skippers: *Polyctor* (left), *Cobalus* (center), and *Neoxeniades* (right). Reared specimens from northwestern Costa Rica, photographed by Daniel H. Janzen. See paper by John M. Burns *et al.*, page 138.

# JOURNAL OF THE LEPIDOPTERISTS' SOCIETY

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## TAXONOMY OF FOUR SPECIES OF EUCOSMINI (TORTRICIDAE) ASSOCIATED WITH *PELOCHRISTA COROSANA* (WALSINGHAM) INCLUDING A NEW SYNONYMY AND DESCRIPTION OF A NEW SPECIES

DONALD J. WRIGHT

3349 Morrison Ave., Cincinnati, Ohio 45220-1430, USA, e-mail: wrightdj@fuse.net

**ABSTRACT.** *Pelochrista gelattana*, new species, is described from Alberta, Utah, and Wyoming. Reviews are included of *P. corosana* (Walsingham) and *P. argenteana* (Walsingham), its two closest congeners based on male genitalia. *Pelochrista idahoana* (Kearfott) is recognized as a junior synonym of *P. argenteana*. *Eucosma nuntia* Heinrich, a species that is similar in many respects to *P. corosana*, is also reviewed. Illustrations detailing the considerable intraspecific variation in wing color and/or male genitalia in the aforementioned taxa are provided, and current distributional information is summarized. A lectotype is designated for *P. argenteana*.

**Additional key words:** Olethreutinae, *Eucosma*, *argenteana*, *idahoana*, *nuntia*.

In Nearctic Olethreutinae, the lineage represented by the genera *Eucosma* Hübner and *Pelochrista* Lederer is comprised of approximately 180 recognized species, with the greatest diversity occurring in the arid and mountainous regions of western North America. There is a long history of confusion regarding species boundaries in the western fauna, the primary contributing factors being the common occurrence of similar looking taxa and the frequent presence of intraspecific variation in both wing color and genitalic characters. Recent progress in resolving some of these problems is reported in Wright (2005, 2007).

This paper is primarily a study of the variation occurring in *Pelochrista corosana* (Walsingham) and *P. argenteana* (Walsingham), western species that share a distinctive form of male genitalia. It was prompted by the recent discovery in southeastern Wyoming of a previously unrecognized member of this group, described below as *Pelochrista gelattana*, new species. A fourth name, *P. idahoana* (Kearfott), which refers to a taxon long considered to be a very close relative of *argenteana*, is recognized here as a junior synonym of *argenteana*.

Heinrich (1929) noted that some phenotypes of *P. corosana* could easily be mistaken for *Eucosma nuntia* Heinrich, based on forewing color and maculation, so a review of the latter species is included. These two taxa are similar not only in forewing pattern but even more strongly so in female genitalia. The male genitalia of

*nuntia* lacks the large spiniform seta at the anal angle of the cucullus associated with members of *Pelochrista*, but in other respects they are quite similar to those of the other species considered here. They also exhibit a range of variation in valval shape that is comparable to that in *argenteana*.

### MATERIALS AND METHODS

This study was based on 497 adult specimens and 78 genitalia preparations from the following collections: American Museum of Natural History (AMNH), George J. Balogh, Canadian National Collection (CNC), University of California Berkeley (UCB), Loran D. Gibson, Mississippi Entomological Museum (MEM), John S. Nordin (JSN), United States Museum of Natural History (USNM), and Donald J. Wright (DJW). Forewing length (FWL) refers to the distance from base to apex (including fringe) and was measured to the nearest one tenth of a millimeter with a graticule mounted in a Leica MZ9s stereomicroscope. Aspect ratio (AR), defined as FWL divided by medial forewing width, is reported as the average of such values calculated for a small sample of specimens. The number of measurements supporting a particular statistic is indicated by n. Forewing pattern terminology follows Brown & Powell (1991) as modified by Baixeras (2002). The digital photographs were edited in Adobe Photoshop CS.

For stability of nomenclature I am designating as lectotype for *argenteana* a specimen selected for that

purpose by Obraztsov. I did not see the specimen itself, but I did examine a 35 mm slide of the adult and a negative of the genitalia, both made by Obraztsov. The included images of the lectotype were obtained by scanning those photographs.

#### SPECIES ACCOUNTS

##### *Pelochrista corosana* (Walsingham)

(Figs. 1–6, 19, 27)

*Paedisca corosana* Walsingham 1884:139, pl. IV, Fig. 6.

*Eucosma corosana*: Fernald [1903]:460; Barnes and McDunnough 1917:171; Heinrich 1923:127, Fig. 219; McDunnough 1939:47.

*Pelochrista corosana*: Powell 1983:35; Miller 1987:55.

**Type.** Holotype: ♂, Montana, Yellowstone R., Morrison, 1880, genitalia slide 11570, BMNH.

**Discussion.** In most specimens of *corosana* the forewing color is olive gray to olive brown (Figs. 3–6). One phenotype from Arizona has a reddish appearance (Fig. 1), and traces of this reddish hue are found in some specimens from New Mexico (Fig. 2). The principal forewing markings are dark olive gray to blackish brown and include an incomplete subbasal fascia running obliquely outward from dorsum to radius and a median fascia from mid costa to the pretoral portion of the dorsum. Occasionally, extensive suffusion of the forewing with dark coloration renders the fasciae barely discernable (Fig. 6). The median fascia is bordered distally by a narrow white line, a feature that is present even in the darkest specimens. Between the white line and the apex there generally is a semitriangular patch of dark scales that connects to a dark apical mark. Most individuals have a streak of white at the base of the fringe along the anterior two thirds of the termen. The ocellus, which is obscure but usually recognizable, is crossed by 3 to 4 black longitudinal streaks (often reduced to black dots) and is bordered basally and distally by variably expressed, silvery-gray, transverse bars. Forewing statistics: ♂ FWL 7.5–10.6 mm (mean = 9.4, n = 31), AR = 3.01, ♀ FWL 7.7–10.5 mm (mean = 9.3, n = 19), AR = 2.94.

**Male genitalia** (Fig. 19): Valva with neck long, apex nearly right-angled, ventral angle produced into triangular projection supporting one stout spine, ventral invagination broad and shallow, proximal margin of medial surface with well developed pulvinus; aedeagus long and narrow, vesica with 5–12 deciduous cornuti (n = 15). **Female genitalia** (Fig. 27): Papillae anales facing laterally and moderately setose; lamella postvaginalis well developed, with posterolateral corners semitriangular; sternum VII with strongly sclerotized and sometimes mildly raised posterior and lateral margins; ductus bursae with sclerotized patch incorporating a distinct fold posterior to juncture with ductus seminalis; corpus bursae with two large signa situated opposite one another on lateral surfaces of the membrane and projecting anteriorly into bursa, adjacent membrane variably wrinkled.

**Distribution and biology.** This moth is widely distributed in western North America and is quite common in the high plains east of the Rocky Mountains. I examined 203 adult specimens (155 ♂, 48 ♀) from Arizona, Colorado, Iowa, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, Texas, and Utah. Capture dates range from June through September. No larval food plant has been reported.

##### *Pelochrista argenteana* (Walsingham)

(Figs. 9–12, 17, 18, 20, 22, 26)

*Paedisca argenteana* Walsingham 1895:504, pl. XII, Fig. 13.

*Eucosma argenteana*: Fernald [1903]:460; Barnes and McDunnough

1917:169; Heinrich 1923:86, Fig. 216; McDunnough 1939:45.

*Pelochrista argenteana*: Powell 1983:35.

*Eucosma idahoana* Kearfott 1907:90; Barnes and McDunnough 1917:169; Heinrich 1923:86, Fig. 217; McDunnough 1939:45,

**new synonymy.**

*Pelochrista idahoana*: Powell 1983:35.

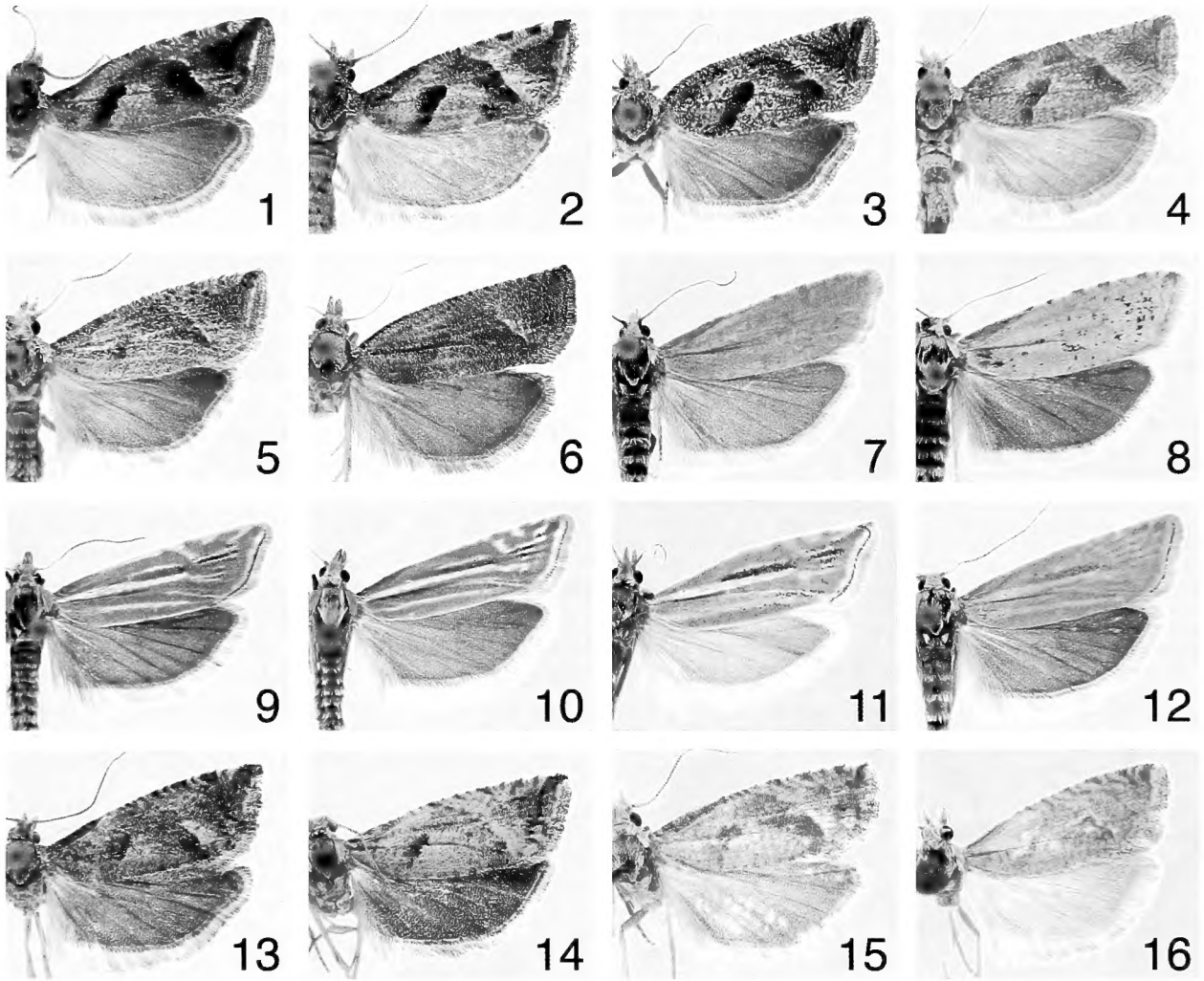
**Types.** *Paedisca argenteana*. Lectotype here designated (Figs. 17, 18): ♂, Loveland, Colorado, July 1891, Smith, genitalia slide 11566, BMNH. *Paralectotypes*: same data as lectotype (3 ♂, 4 ♀), BMNH. *Eucosma idahoana*. Holotype ♂, Blackfoot, Idaho, June 3, Arthur J. Snyder, genitalia slide CH 2 Dec. 1919, AMNH.

**Discussion.** The description of *idahoana* was based on a single male. Kearfott apparently was unaware that this taxon is nearly identical in appearance to *argenteana*. Heinrich (1923) recognized the similarity but treated *idahoana* as a distinct species based on what he considered to be a more olivaceous forewing color and a somewhat differently shaped cucullus. I compared photographs of the *argenteana* lectotype and the *idahoana* holotype and found no significant differences in forewing color. I examined a photograph of the slide prepared by Obraztsov of the *argenteana* lectotype, Heinrich's slide of the *idahoana* holotype, and an additional 18 slides prepared from specimens with the *argenteana-idahoana* forewing pattern. The observed range of variation in the shape of the cucullus is illustrated in Fig. 22. Figure 22b resembles the *idahoana* holotype, Fig. 22e the *argenteana* lectotype. The full range of shapes was found in each of two local populations. I also examined 5 female genitalia preparations and found no significant variation. On these grounds I conclude that *idahoana* should be treated as a junior synonym of *argenteana*.

Differences in *argenteana* forewing appearance, which can be attributed to varying intensities and shades of color, are illustrated in Figs. 9–12. The pattern of maculation is stable and includes silvery-white longitudinal streaking on a straw-yellow background as follows: a narrow costal streak from distal end of fold to apex, a wider streak anterior to cubital vein from base to distal margin of discal cell, a thin line along distal one half of CuA2 terminating at tornus, a narrow streak along IA+2A from base to tornus, and usually a narrow edging along the dorsal margin. The distal one half of the second streak expands to fill the discal cell and is divided longitudinally by a straw yellow bar that is variably overlaid with dark-brown to black scaling. In some specimens (Fig. 12) the white streaks are suffused with straw yellow to the point of being barely distinguishable. Between the cell and the termen there is variably expressed white streaking on the veins, with straw-yellow to brown scaling between the veins. The white streak on R4 is usually joined basally and distally to the costa by short white dashes. The termen is lined with a narrow white band, the distal scales of which have black to brown apices, producing a thin dark line along the base of the fringe. Fringe scales are white basally, shading to pale straw yellow distally. The brown longitudinal streaking varies considerably, but the dark terminal line is always present. Hindwing color varies from dark gray to grayish white (Figs. 9–11). In females it is nearly always grayish white; males exhibit the full range of variation. Forewing statistics: ♂ FWL 7.7–11.4 mm (mean = 9.9, n = 88), AR = 3.53, ♀ FWL 7.6–10.2 mm (mean = 8.7, n = 22), AR = 3.33.

The male genitalia (Figs. 20, 22) are quite similar in general structure to those of *corosana* (Fig. 19), the primary differences being in the shape of the cucullus (at least toward the lower end of the spectrum in Fig. 22) and in the basal projection on the medial edge of the valval opening. The latter is only a small bulge in *argenteana* vs. a fully developed pulvinus in *corosana*. There appears to be a connection between cucullus shape and hindwing color: males with the *idahoana* shape have dark gray hindwings, those with the *argenteana* shape grayish-white. The vesica has 5–11 deciduous cornuti (n = 19).

The most prominent feature of the female genitalia (Fig. 26) is the extensive sclerotization of the ductus bursae, which extends from ostium to corpus bursae and expands anteriorly along the membrane of the bursa into two triangular projections flanking the two signa. The papillae anales face laterally and are sparsely setose, the lamella postvaginalis has acute posterolateral corners, and the concavely



FIGS. 1-16. Adults. 1-6, *P. corosana*. 1, ♂, Coconino Co., Arizona. 2, ♂, Lincoln Co., New Mexico. 3, ♀, Morton Co., Kansas. 4, ♀, Morgan Co., Colorado. 5, ♂, Weld Co., Colorado. 6, ♀, Gove Co., Kansas. 7-8, *P. gelattana*. 7, ♂ holotype. 8, ♂, Albany Co., Wyoming. 9-12, *P. argenteana*. 9, ♂, Albany Co., Wyoming. 10, ♂, Chaffee Co., Colorado. 11, ♀, Weston Co., Wyoming. 12, ♂, Albany Co., Wyoming. 13-16, *E. nuntia*. 13, ♂, Grand Co., Colorado. 14, ♂, Sweetwater Co., Wyoming. 15, ♂, Walla Walla Co., Washington. 16, ♂, Douglas Co., Nevada.

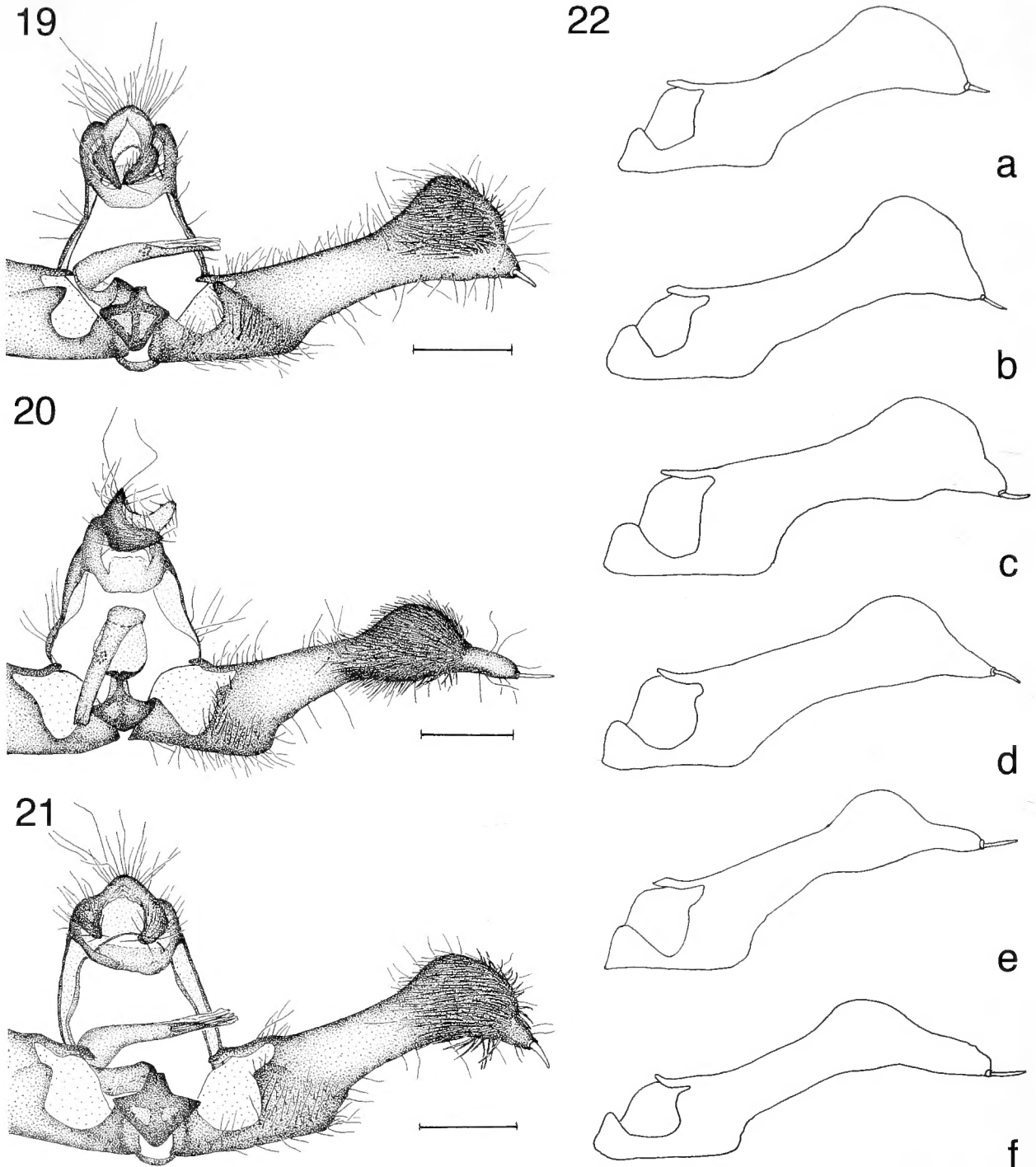


17



18

FIGS. 17-18. Lectotype, *P. argenteana*.



FIGS: 19-22. Male genitalia. 19, *P. corosana*, slide DJW1233. 20, *P. argenteana*, slide DJW1270. 21, *P. gelattana*, slide DJW1287. 22 a-f, *P. argenteana*, slides DJW1271, 1245, 861, 1250, 1270, 1251. Scale bar = 0.5 mm.



emarginated posterior margin of sternum VII has a ventral bulge that weakly shields the ostium.

**Distribution and biology.** I examined 196 specimens (171 ♂, 25 ♀) from Alberta, British Columbia, California, Colorado, Iowa, Montana, New Mexico, North Dakota, Oregon, South Dakota, Saskatchewan, Texas, Utah, and Wyoming. With the exception of one September record from Sioux City, Iowa, all were collected between 30 May and 28 July. No larval host has been reported.

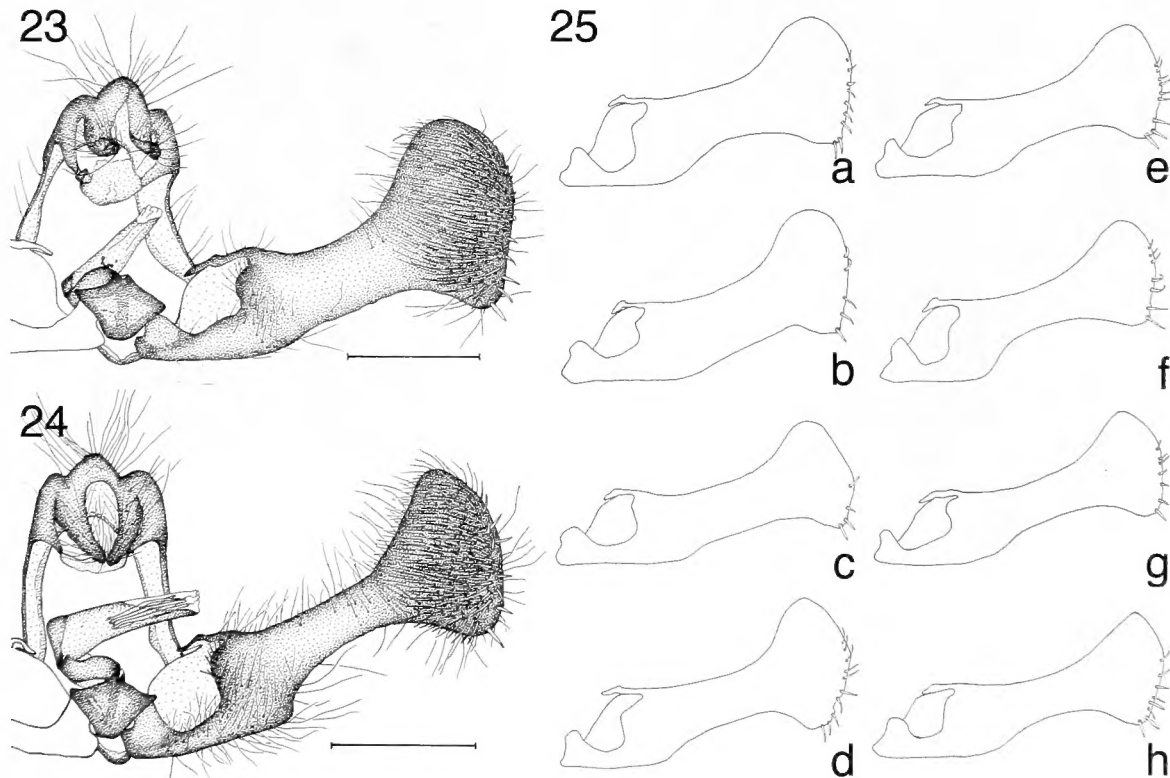
***Pelochrista gelattana*, new species**

(Figs. 7, 8, 21, 29)

**Diagnosis.** The shape of the male valva distinguishes *gelattana* from all Nearctic species of *Pelochrista* except *argenteana* and *corosana*. In most cases these three species are easily separated on the basis of forewing color and maculation. The *argenteana* phenotype with muted white forewing streaking (Fig. 12) might be confused with the non-speckled form of *gelattana* (Fig. 7), but *gelattana* lacks the black terminal line and has several small brown marks on the distal one half of the costa. The female genitalia of the three species are quite distinct (Figs. 26, 27, 29).

**Description.** *Head:* Frons and vertex pale yellowish tan; labial

palpus with basal segment white, medial surface and dorsal margin white, lateral surface tan, third segment concealed by long narrow scales on ventral margin of second segment; dorsal and lateral surfaces of antenna with pale tan scaling. *Thorax:* Dorsal surface concolorous with head; ventral surface creamy white, legs tan to creamy white, distal ends of tarsal segments ringed with white scales, the latter usually inconspicuous on hindleg. *Forewing* (Figs. 7, 8): ♂ FWL 10.2–13.4 mm (mean = 11.9, n = 44), AR = 3.4; ♀ FWL 12.7 mm, AR = 3.34 (n = 1); costa nearly straight, vertex acute, termen straight; dorsal surface uniformly pale yellowish brown, sometimes with very pale reddish-brown overtones, frequently with some blackish-brown tipped scales producing a sparsely speckled effect; male costal fold usually slightly darker than adjacent wing area; ocellus obscure; costal strigulae weakly defined by light brown to blackish-brown marks; fringe scales creamy white basally with very pale tan to brown apices. *Hindwing:* Gray brown to blackish brown, fringe white. *Male genitalia* (Fig. 21): Uncus semitriangular and dorsally setose; dorsolateral shoulders of tegumen moderately developed; socii of medium length, tapering distally, and moderately setose; gnathos a narrow band; aedeagus long and narrow, vesica with 3–8 deciduous cornuti (n = 4); valva with costal margin weakly concave, distal margin convex, ventral invagination broad and shallow, ventral angle produced into moderately long projection supporting one stout spine, cucullus with medial surface densely setose, margin of basal opening with weakly developed pulvinus supporting patch of short stout setae. *Female genitalia* (Fig. 29): Papillae anales large, facing ventrally, finely ridged transversely, and densely setose, setae on lateral margins of lobes long and curving ventrally, those near anal opening with hooked apices, apophyses posteriores short, length ca. 0.33 × that of apophyses anteriores; tergum VIII with long setae along posterior margin; lamella postvaginalis strongly developed, with semirectangular lateral extensions and a shallow central trough from ostium to medial invagination of posterior margin, long setae on lateral extensions and on membrane between sterigma and ventral extremities of tergum VIII; posterior margin of sternum VII with medial, triangular, posteriorly directed projection overlapping ostium; ductus bursae with small sclerotized patch midway between ostium and juncture with ductus seminalis; corpus bursae small, wrinkled, with one small spike-



FIGS. 23–25. Male *E. nuntia* genitalia. 23, slide DJW248. 24, slide DJW1663. 25 a-h, slides USNM70479, 70478, 70472, DJW806, 1747, 1748, USNM70474, DJW1665. Scale bar = 0.5 mm.

shaped signum and one larger thimble-shaped signum.

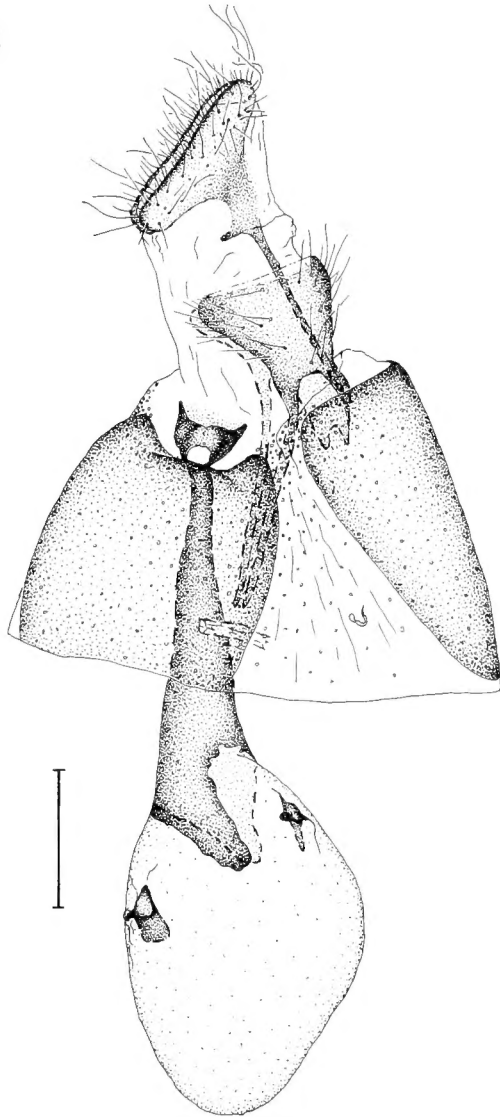
*Holotype* ♂: Wyoming, Albany Co., T15N R75W S29, W. side Gelatt Lake, J. S. Nordin, 6 June 2004, 7250 ft., USNM.

*Paratypes*: ALBERTA: Mannyberries, Dom. Range Sta., D. F. Hardwick, 13 July 1951 (1 ♂, genitalia slide DJW 1358). UTAH: Daggett Co., 4 mi S. of Manila, G. J. Balogh, 20 July 1994 (1 ♀, genitalia slide DJW 711). WYOMING: Albany Co., T15N R75W S29, W. side Gelatt Lake, J. S. Nordin, 7250 ft., 3 June 2004 (2 ♂, genitalia slide DJW 1112), 6 June 2004 (3 ♂, genitalia slides DJW 1286, 1287), 6 June 2006 (5 ♂), 12 June 2006 (3 ♂), 16 June 2005 (1 ♂), 17 June 2005 (4 ♂), 18 June 2005 (4 ♂), 19 June 2005 (1 ♂), 20 June 2005 (2 ♂), 21 June 2005 (5 ♂), 27 June 2005 (2 ♂), 29 June 2006 (5 ♂), 30 June 2005 (2 ♂), 1 July 2005 (3 ♂), 6 July 2005 (3 ♂), 7 July 2005 (1 ♂); 1 mi. E. of Laramie, 2217 Sky View Lane, J. S. Nordin, 8 June 1990 (1 ♂). Paratype depositories: AMNH, BMNH, CNC, Colorado State University, UCB, MEM, JSN, USNM, University of Wyoming, DJW.

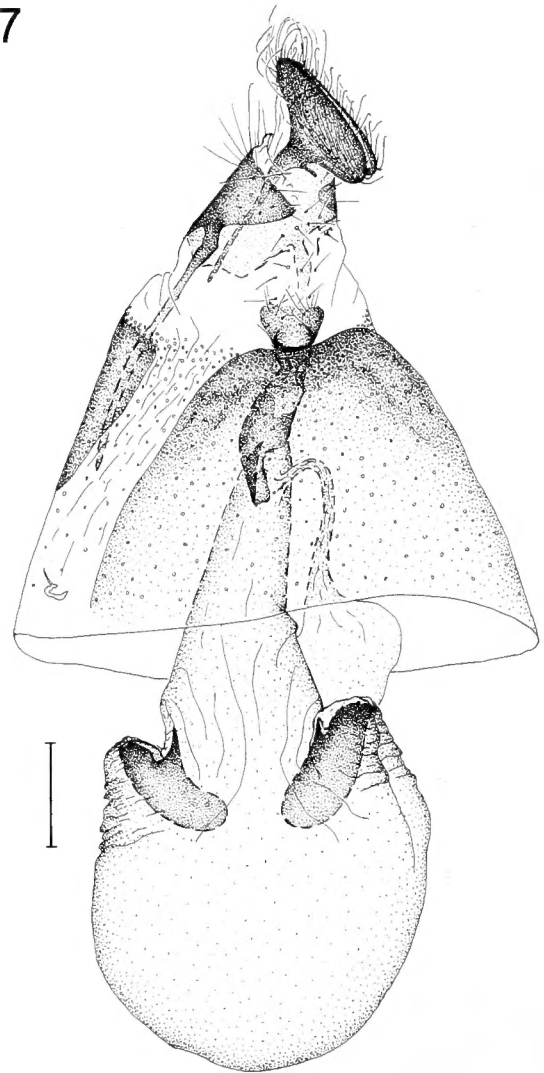
**Etymology.** The specific name derives from the type locality, Gelatt Lake, which is located ca. 15 miles WSW of the city of Laramie in Albany Co., Wyoming.

**Distribution and biology.** The type series consists of 46 males from southeastern Wyoming, one male from the southeast corner of Alberta, and one female from northeastern Utah. These specimens document a flight period extending from early June to mid July. The larval host is unknown. The type locality is noted for its alkali soil. The area surrounding Gelatt Lake has large stands of *Atriplex* (Saltbush), but the traps producing the

26



27



FIGS. 26-27. Female genitalia. 26, *P. argenteana*, slide DJW1246. 27, *P. corosana*, slide DJW1283. Scale bar = 0.5 mm.



*gelattana* specimens were placed near patches of *Gutierrezia* (Snakeweed).

**Discussion.** Three fourths of the *gelattana* specimens exhibited the nearly immaculate forewing illustrated in Fig. 7. The others presented varying amounts of dark speckling, the blackest of which is represented in Fig. 8. The one female specimen reported here is tentatively determined as *gelattana*. It was not collected in association with any males but is identical in appearance and general proportions to the *gelattana* holotype. Despite persistent efforts over two

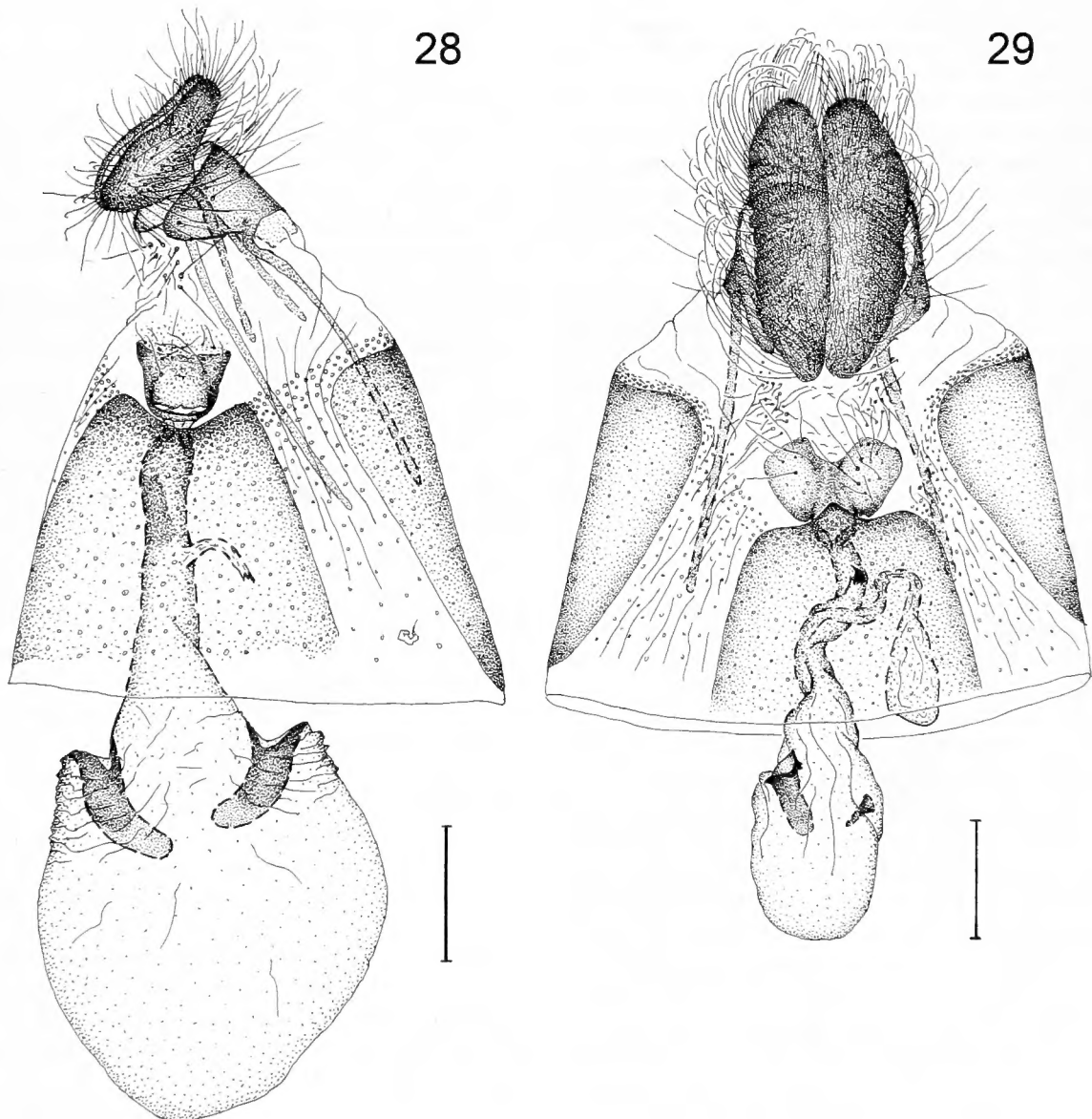
years, only males have been collected at the *gelattana* type locality.

*Eucosma nuntia* Heinrich

(Figs. 13–16, 23–25, 28)

*Eucosma nuntia* Heinrich 1929:10, Fig. 15; McDunnough 1939:47; Powell 1983:35.

**Types.** *Holotype*: ♂, Callao, Juab County, Utah, 17 June 1922, genitalia slide USNM 72811, USNM. *Paratypes*: same locality as holotype, 17 June 1922 (1 ♂), 23 June 1922 (1 ♂), USNM. [Heinrich (1929) reported one male and one female paratype, but the two specimens mentioned above are males, and both bear Heinrich's PARATYPE label. Heinrich erroneously reported the capture dates of



FIGS. 28-29. Female genitalia. 28, *E. nuntia*, slide DJW1664. 29, *P. gelattana*, slide DJW711. Scale bar = 0.5 mm

the holotype and the first paratype as "17-IV-22".]

**Discussion.** In forewing pattern, *nuntia* (Figs. 13–16) resembles *corosana*, but the color tends toward yellow brown rather than olive brown or olive gray. In many of the specimens from the Great Basin the fasciae are very weakly expressed. Similarities with *corosana* include a whitish streak along the distal margin of the median fascia and often some white scaling along the termen. Forewing statistics: ♂ FWL 6.3–10.2 mm (mean = 8.4, n = 29), AR = 2.72; ♀ FWL 8.5–9.7 mm (mean = 9.1, n = 5), AR = 2.93.

I examined 21 genitalia preparations (18 ♂, 3 ♀). Figures 23–25 show the variation in the shape of the valva: apex evenly rounded to acutely angular, neck wide to narrow, corner of sacculus broadly obtuse to nearly right angled, distal margin of cucullus with rounded to angular medial bend, and anal angle variably rounded with 2–3 moderately stout setae. The vesica has 9–15 deciduous cornuti. Figure 25g most closely resembles Heinrich's (1929, Fig. 15) illustration of the holotype. Figures 25a, b, e, f, g illustrate males from a single population at Walla Walla, Washington. The female genitalia are similar to those of *corosana*, but the sclerotization of the ductus bursae does not include a distinct fold.

**Distribution and biology.** I examined 39 adult specimens (34 ♂, 5 ♀) from Colorado, Nevada, Utah, Washington, and Wyoming. Capture dates range from 22 May to 15 August, with roughly two thirds of the records between mid June and mid July. No larval host has been reported.

#### ACKNOWLEDGEMENTS

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THE BUTTERFLY DRAWINGS BY JOHN ABBOT IN THE HARGRETT RARE BOOK AND  
MANUSCRIPT LIBRARY, UNIVERSITY OF GEORGIA.JOHN V. CALHOUN<sup>1</sup>  
977 Wicks Dr., Palm Harbor, FL 34684

**ABSTRACT.** Artist-naturalist John Abbot completed 105 drawings of insects that are now deposited in the Hargrett Rare Book and Manuscript Library, University of Georgia. The provenance of these drawings is unknown, but available evidence dates them to ca. 1820–1825. The adults in the 32 butterfly drawings are identified and the figures of larvae and pupae are assessed for accuracy. The illustrated plants are also identified and their status as valid hosts is examined. Abbot's accompanying notes are transcribed and analyzed. Erroneous figures of larvae, pupae, and hostplants are discussed using examples from the Hargrett Library. At least four of the butterfly species portrayed in the drawings were probably more widespread in eastern Georgia during Abbot's lifetime.

**Additional key words:** Larva, Lepidoptera, pupa, watercolors

In 1776, the English artist-naturalist John Abbot (1751–ca.1840) arrived in Georgia, where he documented species of animals and plants for the next six decades. Living in Burke, Bullock, Chatham, and Screven Counties of eastern Georgia, he explored a region roughly bound by the cities of Augusta and Savannah, between the Oconee, Altamaha, and Savannah Rivers. Abbot longed to expand his travels, writing in 1819, "I had thoughts of taking a Trip to the back State of Tennessee to collect insects and Birds, but I think when Florida is taken possession of and settled by the United States, it will afford an ample field for collecting if Life and health permits" (William Swainson correspondence, Linnean Society of London). Abbot never fulfilled his desire to explore Tennessee and Florida, yet he worked tirelessly in Georgia for the remainder of his life.

Abbot was the first to record thousands of New World species. His drawings and specimens formed the basis of numerous new taxa that were described by prominent American and European naturalists. His drawings continue to serve as an important source of information about the flora and fauna of southeastern North America. However, Abbot's illustrations and written observations often contradict our current understanding of many species (Calhoun 2007). It is helpful to examine his artwork more closely and over the course of his long career in America. I have previously analyzed Abbot's entomological contributions in Calhoun (2003, 2004, 2005, 2006a, 2006b, 2007). As another installment in this study, I present a review of Abbot's butterfly drawings that are preserved in the Hargrett Rare Books and Manuscript Library, University of Georgia.

## METHODS

I visited the Hargrett Rare Book and Manuscript Library (University of Georgia) in April, 2005. Digital photographs were taken of John Abbot's butterfly drawings and their accompanying notes. The adult butterflies were identified and the figures compared with those in other sets of Abbot's drawings that are deposited elsewhere (e.g. the Houghton Library, Harvard University, and the Alexander Turnbull Library, Wellington, New Zealand). Figures of butterfly larvae and pupae were analyzed for accuracy using written descriptions, line drawings, and photographs of living specimens. Botanist Mark A. Garland provided identifications of the depicted plants, which were then evaluated as hosts.

## RESULTS

**Analysis.** The insect drawings by John Abbot in the Hargrett Library are contained in two volumes, each bound in full contemporary brown leather. The gilt spine titles read "MOTHS OF GEORGIA" with an indication of volume number. The board covers are adorned with elaborate gilt borders and blind tooling. Both volumes include yellow marbled endpapers. The volumes are enclosed in a modern rigid black case with a gilt spine title that reads "MOTHS OF GEORGIA/ JOHN ABBOT/WATER-COLOUR MANUSCRIPT."

This set of 105 insect drawings includes Coleoptera (3), Hemiptera (1), Hymenoptera (1), Lepidoptera (99), and Orthoptera (1). The drawings are rendered on cream-colored wove paper, measuring 25.1 × 34.3 cm (9.5 × 13.5 in). Some sheets of paper possess undated watermarks of "T G & C" (T G & Co). This paper was manufactured by Thomas and Joshua Gilpin, whose mill was located north of Wilmington, Delaware from 1787 until 1837 (Gravell & Miller 1979). Other sheets with the watermark of "W B" came from the mills of William

<sup>1</sup>Research Associate, Florida State Collection of Arthropods, DPI, FDACS, Gainesville, Florida 32614, USA

Barber (Barbour), who produced paper in Berks County, Pennsylvania as early as 1808 (Gravell & Miller 1979). Although Abbot employed English papers earlier in his career, he was now primarily using American papers. The Lepidoptera drawings are intended to portray the life history of each species and include figures of the larva, pupa, and a supposed hostplant (Figs. 1–4). Thirty-two of these drawings portray butterflies (Table 1). Drawing no. 9 was figured by Sotheby's (1985a).

The accompanying eleven pages of manuscript notes are included separately and written in Abbot's hand on wove paper measuring 20.7 × 31.8 cm (8.13 × 12.5 in). They are entitled "Notes to the Drawings of Insects" and include numbered entries that correspond to the drawings. Abbot identified the insects and plants in his drawings using either English or Latin names. When he completed these illustrations he was using Latin names more regularly, even though their spelling and application were inexact (Calhoun 2007). The insect and plant names that Abbot used in his notes are inscribed in pencil on many of the drawings in an unknown hand. Based on the calligraphic style, these inscriptions were probably added by an early owner and likely date to the early or mid-nineteenth century. For most butterflies, Abbot recorded the dates that each species "tyed up" (larva suspended prior to pupation), "changed" (pupated), and "bred" (eclosed as an adult). For skipper butterflies of the family Hesperidae, he recorded when the larva "spun up" or "spun up in the leaves" (pupated).

Virtually nothing is known about the provenance of these drawings. In 1985, they were purchased at a Sotheby's auction in London for £11,000 by the London bookseller Maggs Brothers (Sotheby's 1985a, Sotheby's 1985b, Leab & Leab 1986). Sotheby's (1985a) mistakenly believed that they were not the work of Abbot, but instead were "undoubtedly executed by a pupil or imitator." This opinion was based on the higher quality of Abbot's earlier drawings that are preserved in The Natural History Museum, London. Sotheby's (1985a) hesitantly dated the drawings to ca. 1820. Not long after this auction, the volumes were purchased by the New York City bookseller Donald A. Heald, who sold them in 1998 to the University of Georgia (M. E. Brooks pers comm.). Also included in this sale were a set of Abbot's spider drawings and a unique copy of Smith & Abbot (1797) that contains plates printed on vellum (Calhoun 2006a). Owing to the British spelling of "Water-Colour" on the spine, the black case was added by either Sotheby's or Maggs Brothers. The name "J. McDougal" is inscribed in modern blue ink on a flyleaf of each volume. This is possibly the signature

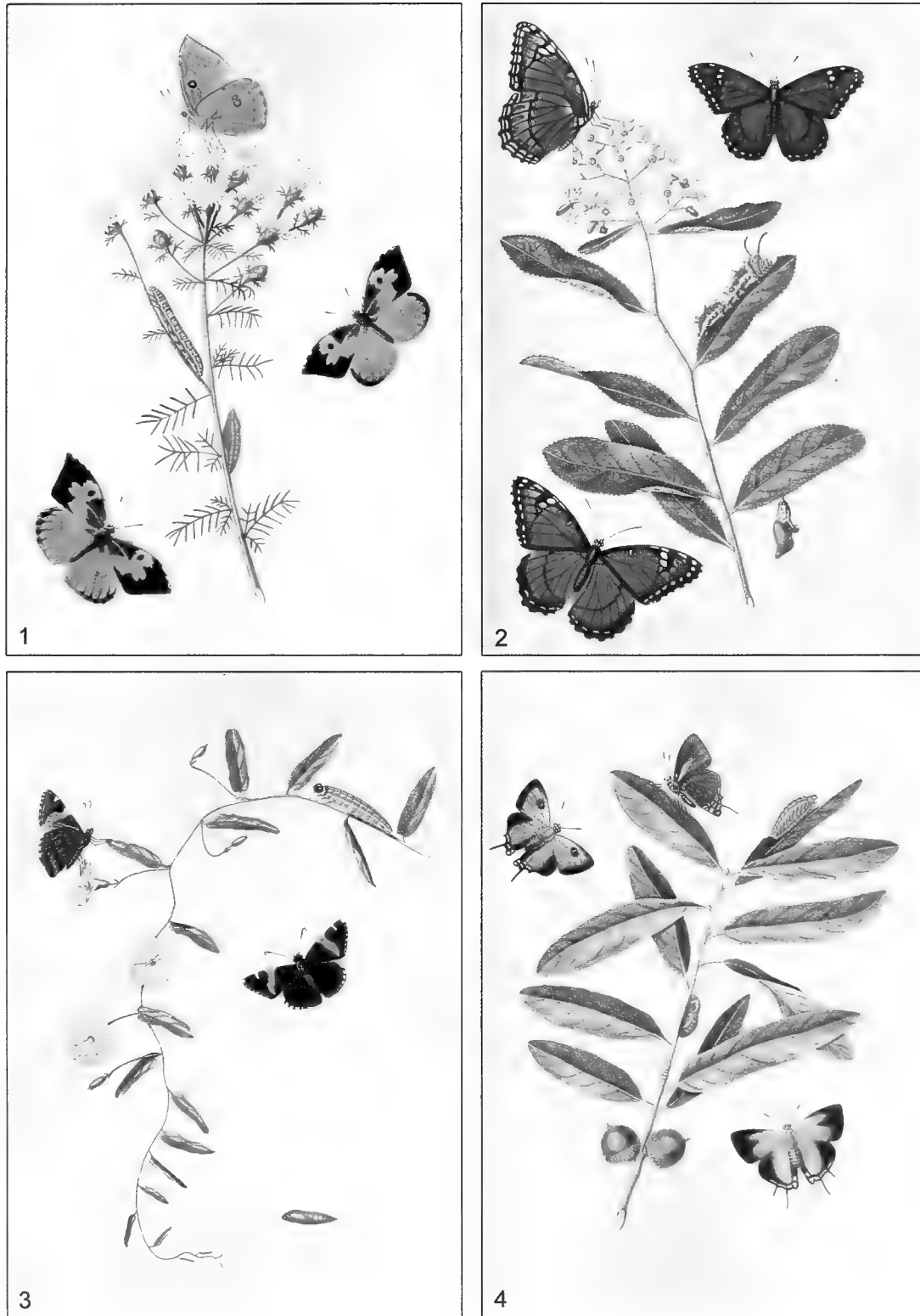
of the consignee for the Sotheby's auction. Sotheby's (1985a) did not identify the prior owner.

**Completion.** Because nothing is known about the early history of these drawings, existing evidence was used to determine their age. Aspects of Abbot's artistic methods and written observations were discussed in Calhoun (2006a, 2007). The Hargrett Library drawings are arranged in simple numerical order and are not haphazardly numbered like drawings that Abbot had completed ca. 1800–1810. Many of the butterfly compositions are duplicates of Abbot's life history drawings, ca. 1810–1815, that were copied for color plates in Boisduval & Le Conte (1829–[1837]) (Calhoun 2004). Entries in the accompanying notes for those drawings are also similar to the Hargrett Library notes. A large number of the Hargrett Library drawings are duplicated within a set of 103 watercolors that Abbot completed between 1816 and 1818 for the English naturalist William Swainson (Calhoun 2007). The associated notes and watermarks of these drawings are likewise very similar. Although Abbot duplicated compositions for many years, the diminished quality of the Hargrett Library drawings is reminiscent of his later work. It seems that Abbot abandoned life history drawings during the late 1820s in favor of less complex geometric patterns of adult insects.

Abbot employed a greater number of Latin names for the Hargrett Library drawings than those for William Swainson. Over the years, Abbot less often recorded when butterfly larvae "tyed up." The notes for the Swainson drawings include 17 such references, while those at the Hargrett Library include only three. Some of the Hargrett Library notes incorporate additional comments that are not found in the Swainson set. The binding of the Hargrett Library volumes is very similar to copies of Smith & Abbot (1797) that were bound in Britain around 1825 (Calhoun 2006a). Based on this evidence, the Hargrett Library drawings were probably completed ca. 1820–1825. They may represent some of Abbot's last drawings of this type. After residing in London for over 160 years, the drawings were returned to within 270 km (168 mi) of their origin in Bullock Co., Georgia, where Abbot lived from 1818 until his death.

#### DISCUSSION

**Erroneous associations.** Abbot's life history drawings frequently deviate from reality and those in the Hargrett Library are no exception. His figures of larvae and pupae are sometimes inconsistent with the associated adults. Others are too imprecise to identify, clearly fabricated, or "borrowed" from his illustrations of other species. The depicted hostplants are often untenable or require confirmation (Calhoun 2006a,



FIGS. 1-4. John Abbot butterfly drawings in the Hargrett Library. 1, *Zerene cesonia* (no. 17). 2, *Limenitis archippus* (no. 10). 3, *Autochton cellus* (no. 21). 4, *Atlides halesus* (no. 31) (erroneous larva and hostplant).

TABLE 1. Adult butterflies, early stages, and plants depicted in John Abbot drawings in the Hargrett Rare Book and Manuscript Library. Abbot's original manuscript entries are included for each (Abbot's grammar and spelling are preserved). Insect nomenclature follows Opler & Warren (2003). Adult insect figures: D=dorsal, V=ventral, m=male, f=female. Early stages: L=larva, P=pupa, a=acceptable, u=unacceptable. Status of figured hostplants (in brackets): C=confirmed, NC=needs confirmation, E=erroneous.

Drawing No.	Figured adults and early stages	Plant species and host status	Manuscript entry by J. Abbot
6	<i>Papilio glaucus</i> Linnaeus Df, Vf, La, Pa	<i>Styrax americanus</i> Lam. (Styracaceae) [C]  "Styrax laevigata" is a synonym of <i>S. americanus</i> . "Swamp Ash" (probably <i>Fraxinus pennsylvanica</i> Marsh.) (Oleaceae) and "Hicory" [hickory] ( <i>Carya</i> sp.) (Juglandaceae) are also confirmed hostplants.	6. <i>Papilio Glaucus</i> . The Caterpillar feeds on the plant figured, <i>Styrax laevigata</i> , Swamp Ash and Hicory. Tied itself up by the tail 11 <sup>th</sup> Oct <sup>r</sup> Changed the 13 <sup>th</sup> into Chrysalis. The Butterfly was bred 2 <sup>d</sup> April. It also breeds again in the Summer. The Caterpillar is very rare, and the Butterfly not common.
7	<i>Papilio cresphontes</i> Cramer Dm, Vm, La, Pa	<i>Xanthoxylum clava-herculis</i> L. (Rutaceae) [C]  "Xanthoxylum Clava sterenlus" is a misspelled reference to <i>Z. clava-herculis</i> (Rutaceae). "Orange tree" ( <i>Citrus</i> sp.) (Rutaceae) is also a confirmed hostplant.	7. <i>Papilio Thoas</i> . Feeds on the <i>Xanthoxylum Clava sterenlus</i> , and the orange tree. Tied up the 6 <sup>th</sup> May; changed the 7 <sup>th</sup> bred 27 <sup>th</sup> another that changed the 15 <sup>th</sup> May, was bred 3 <sup>d</sup> June, and another that changed the 30 <sup>th</sup> June, bred 19 <sup>th</sup> July. It frequents in, and in the neighbourhood of Savannah, but is not to be met with a few miles inland.
8	<i>Papilio glaucus</i> Linnaeus Dm, Vm, La, Pa	<i>Ptelea trifoliata</i> L. (Rutaceae) [C]  "Swamp Ash" (probably <i>Fraxinus pennsylvanica</i> Marsh.) (Oleaceae) is also a confirmed hostplant.	8. <i>Papilio Eq. Gr. Turnus</i> . Feeds on the <i>Ptelea trifoliata</i> , and Swamp Ash, changed the 20 <sup>th</sup> June, bred 4 <sup>th</sup> July. May be met with thinly scattered in most parts of the Country
9	<i>Papilio palamedes</i> Drury Dm, Vm, La, Pa	<i>Magnolia virginiana</i> L. (Magnoliaceae) [E]  "Magnolia Glauca" is a synonym of <i>M. virginiana</i> .	9. <i>Papilio Chalcas</i> . Feeds on the <i>Magnolia Glauca</i> , changed the 31 <sup>st</sup> May, bred 14 <sup>th</sup> June another that changed the 18 <sup>th</sup> Sep <sup>r</sup> bred the 24 <sup>th</sup> March. Continues to breed all the Summer, and is frequent all over the Country

NOTES: only the dark form of the female is portrayed. Duplicate figures by Abbot were reproduced for Plates 8 and 9 of Boisduval & Le Conte (1829–[1837]). It is interesting that Abbot followed contemporary wisdom in treating this form as a separate species from the butterflies in drawing no. 8, especially since he reared both and noted that each fed on "Swamp Ash". Moreover, he portrayed slightly different immatures in these drawings. Abbot possibly knew the truth about this form, but was hesitant to refute more "learned" naturalists who were also paying customers.

NOTES: duplicate figures by Abbot were reproduced for Plates 12 and 13 of Boisduval & Le Conte (1829–[1837]). The cultivation of orange trees was probably responsible for the occurrence of this butterfly "in the neighbourhood of Savannah." Specimens of *P. cresphontes* were generally identified as *Papilio thoas* Linnaeus until they were recognized as a different species.

NOTES: see drawing no. 6. Duplicate figures by Abbot were reproduced for Plates 6 and 7 of Boisduval & Le Conte (1829–[1837]). Abbot's name for the butterfly was derived from the Linnaean classification system; "Eq." refers to the group *Equites* (*Eques*) and "Gr." a mistake for "Tr." refers to the subgroup *Trojani* (*Troës*). This subgroup is also in error, as the name *Papilio turnus* L. was originally placed by Linnaeus into the subgroup *Achivi*.

NOTES: a duplicate drawing by Abbot was figured in Calhoun (2007). Duplicate figures of the larva and pupa by Abbot were reproduced for Plate 5 of Boisduval & Le Conte (1829–[1837]). The erroneous association of this butterfly with *Magnolia virginiana* was discussed in Calhoun (2007). The pupa is too colorful, but conceptually accurate. "*Papilio Chalcas*" (i.e. *Papilio chalcas* Fabricius) is now considered to be a junior synonym of *P. palamedes*.



TABLE 1. Continued

Drawing No.	Figured adults and early stages	Plant species and host status	Manuscript entry by J. Abbot
10	<i>Limenitis archippus</i> (Cramer)  Dm, Df, Vf, La, Pa	<i>Licania michauxii</i> Prance (Chrysobalanaceae) [NC]  "Papaw" apparently refers to the depicted plant (commonly known as gopher apple), though Abbot validly used this name for species of <i>Asimina</i> (Annonaceae). "Willow" ( <i>Salix</i> sp.) (Salicaceae) is a valid hostplant.	10. Black veined orange Butterfly. Feeds on the species of Papaw figured, but is most frequent on Willow changed the 31 <sup>st</sup> July, bred 7 <sup>th</sup> August, neither the Caterpillar or Butterfly is common.
NOTES: see Fig. 1. Portions of a duplicate drawing by Abbot were reproduced for Plate 55 of Boisduval & Le Conte (1829–[1837]). The depicted plant may be the result of an association error or an aesthetic substitution. Based on a penciled inscription on a duplicate drawing at Harvard University, Scudder (1888–1889) identified the plant as <i>Chrysobalanus oblongifolius</i> Michx., which is now considered to be a synonym of <i>L. michauxii</i> .			
11	<i>Astererocampa clyton</i> (Boisduval & Le Conte)  Dm, Df, Vf, La, Pu	<i>Vaccinium stamineum</i> L. (Ericaceae) [E]  "Sugarberry" refers to <i>Celtis</i> .	11. Orange coloured Butterfly. Feeds on the wild Gooseberry, changed 21 <sup>st</sup> May, bred 9 <sup>th</sup> June, is very rare.
NOTES: Calhoun (2007) figured a duplicate drawing by Abbot and discussed the erroneous larva, pupa, and hostplant in this composition (see text). Scudder (1888–1889) identified the larva as <i>P. interrogationis</i> and the pupa as <i>Polygonia comma</i> (Harris). However, I have found no evidence that Abbot ever encountered <i>P. comma</i> in Georgia, nor does the larva resemble that species.			
12	<i>Chlosyne gorgone</i> (Hübner)  Dm, Df, Vm, La, Pa	<i>Helianthus divaricatus</i> L. (Asteraceae) [C]  "Cross wort" apparently refers to <i>H. divaricatus</i> (see Calhoun 2003). This is possibly a misapplication of a common name for the British yellow-flowered herb, <i>Cruciata laevipes</i> Opiz (Rubiaceae). "Sunflower" probably indicates another species of <i>Helianthus</i> .	12. Cross wort Fritillary Butterfly. Feeds on the Cross wort, and sunflower, changed 17 <sup>th</sup> May, bred 26 <sup>th</sup> . Frequents the Oak Woods of Burke County but is not in the lower parts of the Country.
NOTES: : this drawing was figured in Parkinson & Rogers-Price (1984) and Calhoun (2003). Duplicate figures by Abbot were reproduced for Plate 46 of Boisduval & Le Conte (1829–[1837]) to accompany the original description of the enigmatic taxon <i>Melitaea ismeria</i> (Calhoun 2003, 2004, 2005). It is believed that Abbot's mention of "the lower parts of the Country" refers to bottomland habitats. This phrase, not included in the accompanying notes for three other known duplicates of this drawing, offers further evidence that Abbot did not consider <i>C. gorgone</i> to be the same species as <i>Chlosyne nycteis</i> (Doubleday) as suggested by Gatrell (2003). The larva in this composition is conceptually consistent with <i>C. gorgone</i> . "Fritillary" is a misspelling of the British name "Fritillary."			
13	<i>Phyciodes phaon</i> (Edwards)  Dm  <i>Phyciodes tharos</i> (Drury)  Df, Vf, La, Pa	<i>Chrysopsis mariana</i> (L.) Elliott (Asteraceae) [NC/E]	13. Small Fritillary Butterfly. Feeds on the flower figured, changed the 10 <sup>th</sup> June, bred 21 <sup>st</sup> . The Caterpillar is rare, but the Butterfly is frequent in all parts of the Country, the whole Summer.
NOTES: Abbot obviously did not distinguish between these two species of butterflies. The larva and pupa are most consistent with <i>P. tharos</i> . The plant may be a possible natural host of <i>P. tharos</i> , but not of <i>P. phaon</i> , which is known to feed almost exclusively on species of <i>Phyla</i> (Verbenaceae) (see text).			
14	<i>Asterocampa celtis</i> (Boisduval & Le Conte)  Dm, Df, Vm, Lu, Pa	<i>Celtis cf. tenuifolia</i> Nutt. (Celtaceae) [C]  "Sugarberry" refers to the figured <i>Celtis</i> .	14. Papilio Portlandia. Feeds on the Sugar berry, changed 7 <sup>th</sup> May, bred 20 <sup>th</sup> . Is very rare
NOTES: portions of a duplicate drawing by Abbot were reproduced on Plate 57 of Boisduval & Le Conte (1829–[1837]) to accompany the original description of this species. The larva, and possibly also the pupa, is <i>A. clyton</i> (see drawing no. 11). Boisduval & Le Conte (1829–[1837]) and Scudder (1888–1889) identified the depicted plant as <i>Celtis occidentalis</i> L. (Celtaceae). Abbot repeatedly misapplied the name "Papilio Portlandia" (i.e. <i>Papilio portlandia</i> Fabricius) to this species (Calhoun 2007).			

TABLE 1. Continued

Drawing No.	Figured adults and early stages	Plant species and host status	Manuscript entry by J. Abbot
15	<i>Libytheana carinenta</i> (Cramer) Dm, Vm, La, Pa	<i>Celtis cf. tenuifolia</i> Nutt. (Celtaceae) [C] "Sugarberry" and "Hackberry" refers to <i>Celtis</i> .	15. Snout Butterfly. Feeds on the Sugarberry, or Hackberry, changed 29 <sup>th</sup> April, bred 8 <sup>th</sup> May, is rare.
NOTES: a duplicate drawing by Abbot was figured in Calhoun (2004). With the exception of the adult figures, most of another duplicate drawing by Abbot was reproduced for Plate 64 of Boisduval & Le Conte (1829–[1837]). Scudder (1888–18889) identified the plant in duplicate drawings as <i>Celtis occidentalis</i> L. (Celtaceae). Species of Libytheidae have long been called "Snout" butterflies in Britain.			
16	<i>Ascia monuste</i> (Linnaeus) Dm, Df(2), Vf, La, Pa	<i>Cleome gynandra</i> L. (Capparaceae) [C] "Cleome pentaphyllas," a misspelling of <i>C. pentaphylla</i> L., is a synonym of <i>C. gynandra</i> .	16. White Butterfly Vanessa. Feeds on the Cleome pentaphyllas. changed 17 <sup>th</sup> July, bred 23 <sup>rd</sup> , many of the female Butterflies varies being of a dingy black as figured, They are some Years in plenty in, and about Savannah.
NOTES: duplicate drawings by Abbot were figured in Gilbert (1998) and Calhoun (2004). Duplicate figures by Abbot were reproduced for Plate 16 of Boisduval & Le Conte (1829–[1837]) (Calhoun 2004). Abbot's notes aptly describe the irregular migratory presence of the subspecies <i>A. m. phileta</i> (Fabricius) in coastal Georgia (Calhoun 2004). Abbot's name for this species, "Vanessa," is misapplied. In an 1813 letter, the botanist William Baldwin noted that the figured hostplant, <i>C. gynandra</i> , grew "spontaneously about the suburbs of Savannah" (Darlington 1843).			
17	<i>Zerene cesonia</i> (Stoll) Dm, Df, Vm, La, Pa	<i>Dalea pinnata</i> (J. F. Gmelin) Barneby (Fabaceae) [C]	17. Clouded yellow Butterfly, P. Philippi. Feeds on the plant figured, changed 19 <sup>th</sup> April, bred 2 <sup>d</sup> May, continues to breed all the Summer and Autumn. Is most common in the Pine woods. often settles several together to suck the moist places in roads, and other places.
NOTES: see Fig. 1. The late season form of this species is portrayed. Duplicate figures of the larva and pupa by Abbot were reproduced for Plate 22 of Boisduval & Le Conte (1829–[1837]). Boisduval & Le Conte misidentified the depicted plant as <i>Tagetes papposa</i> Vent., a synonym of <i>Dyssodia papposa</i> (Vent.) Hitchc. (Asteraceae). Abbot's Latin name, "P. Philippi," is a misspelling of <i>Papilio phillipa</i> Fabricius, a junior synonym of <i>Papilio cesonia</i> .			
18	<i>Cercyonis pegala</i> (Fabricius) Dm, Df, Vf, La, Pa	<i>Panicum</i> sp, possibly <i>P. dichotomiflorum</i> Michx. or <i>P. rigidulum</i> Nees (Poaceae) [NC]	18. Great meadow brown Butterfly. Feeds on the grass figured, and other grasses, changed 20 <sup>th</sup> June, bred 5 <sup>th</sup> July. Frequents the Pine woods, is not common.
NOTES: portions of a duplicate drawing by Abbot were reproduced for Plate 59 of Boisduval & Le Conte (1829–[1837]) (the figure of the larva was reversed). Additional comments about this composition were included in Calhoun (2007). Abbot's English name for this butterfly was derived from its superficial resemblance to the common European butterfly, <i>Maniola jurtina</i> (L.), known in Britain as the meadow brown since the early eighteenth century.			
19	<i>Cyllopsis gemma</i> (Hübner) Dm, Df, Vm, Lu, Pu	<i>Panicum</i> sp. (Poaceae) [NC] This species feeds on grasses, but natural hostplants are poorly known.	19. Swamp brown Butterfly. Feeds on the grass figured and other grasses, Tied up 10 <sup>th</sup> April, changed the 11 <sup>th</sup> bred 24 <sup>th</sup> . Frequents Swamps and hammocks, is not common.
NOTES: most of a duplicate drawing by Abbot was reproduced for Plate 62 of Boisduval & Le Conte (1829–[1837]). The head of the depicted larva lacks the distinctive horns of this species. This same figure of the larva is found in at least two of Abbot's drawings of <i>Hermeupychia sosybius</i> (drawing no. 20), suggesting that he "borrowed" it to illustrate the life history of <i>C. gemma</i> . Moreover, the pupa in this drawing also lacks horns and is consistent with <i>H. sosybius</i> .			

TABLE 1. Continued

Drawing No.	Figured adults and early stages	Plant species and host status	Manuscript entry by J. Abbot
20	<i>Hermeupychia sosybius</i> (Fabricius) Dm, Df, Vm, Lu, Pa	<i>Carex</i> sp., possibly <i>C. hyalinolepis</i> Steudel (Cyperaceae) [NC]	20. Small Ringlet Butterfly. Feeds on the Grass figured, and other grasses, changed 24 <sup>th</sup> August, bred 11 <sup>th</sup> Sep <sup>r</sup> . Frequents the Swamps and fields, is frequent in most parts.
NOTES: this butterfly is known to feed only on grasses (Poaceae). Abbot may have collected the wrong plant for his illustration, possibly confusing it with the host of <i>Neonympha areolatus</i> (J. E. Smith), which feeds on sedges (Cyperaceae). To Abbot, sedges were simply "grasses." The depicted larva lacks the pair of posterior appendages that are found in this species. Abbot included a more accurate larva in at least two other drawings of this species, but later applied it to <i>C. gemma</i> (see drawing no. 19 and text). The name "Ringlet" was derived from its remote similarity to the widespread European species, <i>Aphantopus hyperantus</i> (L.), which has been known as the ringlet in Britain since the mid-eighteenth century.			
21	<i>Autochton cellus</i> (Boisduval & Le Conte) Dm, Vm, La, Pa	<i>Stylisma aquatica</i> (Walter)Raf. (Convolvulaceae) [E] This plant was previously placed in the genus <i>Convolvulus</i> L. as indicated by Abbot.	21. Barr'd Skipper Butterfly. Feeds on the Convolvulus figured, spun up 4 <sup>th</sup> April, bred 25 <sup>th</sup> . Frequents the sides of Swamps, is rare.
NOTES: see Fig. 3. Most of a duplicate drawing by Abbot was reproduced for Plate 73 of Boisduval & Le Conte (1829–[1837]), representing the "original description" of this species. This skipper feeds almost exclusively on <i>Amphicarpaea bracteata</i> (L.) Fern. (Fabaceae) in eastern North America (Burns 1984). Abbot's depiction is either an aesthetic substitution or he misidentified the plant when he collected samples for this composition. Scudder (1888-1889) identified the plant on the published plate in Boisduval & Le Conte (1829–[1837]) as <i>Breweria aquatica</i> (Walter) A. Gray, which is now considered to be a synonym of <i>S. aquatica</i> . The pupa is conceptually accurate, but should be stouter in shape.			
22	<i>Problema bulenta</i> (Boisduval & Le Conte) Dm, Df, Vm, La, Pa	<i>Panicum</i> sp., possibly <i>P. dichotomiflorum</i> Michx. or <i>P. virgatum</i> L. (Poaceae) [NC]  "Broad grass" refers to this or a similar species of grass.	22. Broad grass Skipper Butterfly. Feeds on the broad grass, folding itself in the leaf, changed 25 <sup>th</sup> July, bred 6 <sup>th</sup> August. Frequents Rice fields, ditches, and the sides of ponds in the lower parts of Georgia. Is not common.
NOTES: duplicate figures by Abbot were reproduced for Plate 67 of Boisduval & Le Conte (1829–[1837]), representing the "original description" of this species. Rather than <i>Panicum</i> , Abbot possibly found his larvae on <i>Zizania aquatica</i> L. (Poaceae) or <i>Zizaniopsis miliacea</i> (Michx.) Döll & Asch. (Poaceae) (Calhoun 2007).			
23	<i>Euphyes arpa</i> (Boisduval & Le Conte) Dm, Df, La, Pa	<i>Rhynchospora latifolia</i> (Baldwin) W.W. Thomas (Cyperaceae) [NC]	23. Georgia Skipper Butterfly. Feeds on the Grass figured, and other grasses, spun up 25 <sup>th</sup> March, bred 12 <sup>th</sup> April. Frequents the sides of ponds in the pine woods, is rare.
NOTES: most of a duplicate drawing by Abbot was reproduced for Plate 68 of Boisduval & Le Conte (1829–[1837]), representing the "original description" of this species. This skipper normally feeds on <i>Serenoa repens</i> (Bartram) Small (Palmae), but Minno (1994) reared it on a species of Cyperaceae, suggesting that Abbot could have successfully reared it on this sedge (Calhoun 2004). The larva is conceptually accurate.			
24	<i>Thorybes bathyllus</i> (J. E. Smith) Dm, Df, Vf, La, Pa	<i>Desmodium</i> sp., possibly <i>D. paniculatum</i> (L.) DC. (Fabaceae) [C]  "Begger's lice" refers to the figured <i>Desmodium</i> .	24. Brown Skipper. Feeds on the Beggers lice (figured) spun up in the leaves 18 <sup>th</sup> Oct <sup>r</sup> bred 20 <sup>th</sup> April, is not very common
NOTES: a duplicate of this drawing was reproduced in ATLET (1983). It was also figured by Reynolds (1983) and Rogers-Price (1983). Portions of another duplicate drawing by Abbot were reproduced for Plate 74 of Boisduval & Le Conte (1829–[1837]). Although I have tentatively identified the figures in this composition as <i>T. bathyllus</i> (also see Calhoun 2007), some characters are reminiscent of <i>Thorybes confusus</i> Bell, making it difficult to determine the species with certainty. The plant was identified in ATLET (1983) as <i>Desmodium fernaldii</i> B.G. Schub. (Fabaceae).			

TABLE 1. Continued

Drawing No.	Figured adults and early stages	Plant species and host status	Manuscript entry by J. Abbot
25	<i>Pyrgus communis</i> (Grote)  Dm, Df, Vf, La, Pa	<i>Sida acuta</i> Burm. f. (Malvaceae) [C]	25. Black and white Skipper. Feeds on the plant figured, spun up in the leaves 25 <sup>th</sup> June, bred 7 <sup>th</sup> July. Is to be met with in the Oak woods and fields, is not common.
NOTES: a duplicate drawing by Abbot was figured by Calhoun (2007). The skippers portrayed in this drawing are almost certainly <i>P. communis</i> , as there is no evidence that the similar <i>Pyrgus albescens</i> Plötz occurred in Georgia during Abbot's lifetime (Calhoun 2007).			
26	<i>Ancyloxypha numitor</i> (Fabricius)  Dm, Df, Vm, La, Pa	<i>Justicia ovata</i> (Walter)Lindau (Acanthaceae) [E]	26. Least yellow Skipper. Feeds on the plant figured, changed 12 <sup>th</sup> Sepr bred 22 <sup>d</sup> . Is frequent in Rice fields, and meadowy parts of branches.
NOTES: this species is a grass-feeder. <i>Justicia</i> grows in the wet habitats where this skipper occurs, thus Abbot may have confused the host. However, an earlier composition of <i>A. numitor</i> by Abbot includes another erroneous host, <i>Asclepias verticillata</i> L. (Apocynaceae), which occurs in dry soils. Abbot ambiguously referred to both plants as "the plant figured," suggesting that he did not recall the proper host or inserted these more colorful plants to enhance his compositions.			
27	<i>Erynnis martialis</i> (Scudder)  Dm, Df, Vf, La, Pa	<i>Indigofera caroliniana</i> Mill. (Fabaceae) [E]  In this case, "Wild Indigo" apparently refers to <i>Indigofera</i> , not a species of <i>Baptisia</i> (Fabaceae). "Red root, or red shank" refers to <i>Ceanothus americanus</i> L. (Rhamnaceae), a confirmed hostplant	27. Least dingy Skipper. Feeds on the Wild Indigo, and Red root, or red shank, Spun up in the leaves 25 <sup>th</sup> June, bred 8 <sup>th</sup> July, Frequents the Oak woods, is much less frequent than the other Dingy Skippers.
NOTES: this species is known to feed only on <i>Ceanothus americanus</i> L. (Rhamnaceae) in eastern North America. In fact, Abbot illustrated this skipper with <i>C. americanus</i> for an earlier composition, calling the plant "Red shank or red Root" (see text). Abbot's mistaken recollection of an alternate host may have resulted in the inclusion of <i>I. caroliniana</i> . He called all species of the genus <i>Erynnis</i> "Dingy Skippers," after the European <i>Erynnis tages</i> (L.), which has long been called the dingy skipper in Britain.			
28	<i>Pholisora catullus</i> (Fabricius)  Dm, Df, Vf, La, Pa	<i>Monarda punctata</i> L. (Lamiaceae) [E]  "Rignum" is an old name for <i>M. punctata</i> . "Horse mint" is also a name for this plant. "Careless" ( <i>Amaranthus</i> sp.) (Amaranthaceae) and "lambs quarter" ( <i>Chenopodium</i> sp.) (Amaranthaceae) are confirmed hostplants.	28. Black Skipper Catullus. Feeds on the plant figured called here Rignum and horse mint, common and red careless, and lambs quarter. Spun up 18 <sup>th</sup> June, bred 26 <sup>th</sup> another that spun up 29 <sup>th</sup> July, was bred the 5 <sup>th</sup> August, The Butterfly is frequent in Corn fields and plantations in Burke County.
NOTES: another drawing of this species by Abbot, which included duplicate figures of larva and pupa, was reproduced for Plate 24 of Smith & Abbot (1797) (Calhoun 2006a). Abbot's notes for that earlier drawing include some of the same life history data as for this illustration. Abbot created at least three compositions of this species and all depict <i>Monarda</i> , probably because it is more visually appealing than the true hosts.			
29	<i>Amblyscirtes alternata</i> (Grote & Rrobinson)  Dm, Df, La, Pa	<i>Sorghastrum secundum</i> (Elliott)Nash (Poaceae) [NC]  "Wild Oats" apparently refers to the depicted grass. Hostplants of this rare skipper are poorly known.	29. Little brown Skipper. Feeds on the wild Oats, spun up in the leaves 31 <sup>st</sup> May, bred 14 <sup>th</sup> June. The Caterpillar is very rare. The Butterfly frequents the pine woods, but is not common.
NOTES: Abbot portrayed fresh specimens of <i>A. alternata</i> , which can be boldly marked as in this drawing, especially ventrally. Duplicate figures were misidentified by Scudder (1872, 1888–1889) and Beirne (1950) as <i>Amblyscirtes hegon</i> (Scudder) (see text).			

TABLE 1. Continued

Drawing No.	Figured adults and early stages	Plant species and host status	Manuscript entry by J. Abbot
30	<i>Feniseca tarquinius</i> (Fabricius)  Dm, Df, Lu, Pa	<i>Vaccinium arboreum</i> Marshall (Ericaceae) [E]  "Winter Huckleberry" apparently refers to the depicted plant. "Alder" undoubtedly refers to <i>Alnus serrulata</i> (Aiton)Willd. (Betulaceae), which is also an erroneous hostplant.	30. Little orange Butterfly. Feeds on the winter Huckleberry, but is most frequent on Alder, it is partly covered with a white loose down, changed the 14 <sup>th</sup> of April, bred the 25 <sup>th</sup> . The Butterfly frequents Swamps, but is rare.
NOTES: duplicate figures by Abbot were reproduced for Plate 37 of Boisduval & Le Conte (1829–[1837]). This butterfly feeds only on species of aphids (see text). The depicted larva is a slightly altered version of Abbot's larva of <i>Callophrys niphon</i> (Hübner), which is very unlike the spiny and more mottled larva of <i>F. tarquinius</i> (see text).			
31	<i>Atlides halesus</i> (Cramer)  Dm, Df, Vm, Lu, Pa	<i>Quercus phellos</i> L. (Fagaceae) [E]  "Willow Oak" is a common name for <i>Q. phellos</i> , which Abbot misspelled as "phillos."	31. Great Purple hair Streak Butterfly. Feeds on the Willow Oak, <i>Quercus phillos</i> , changed the 20 <sup>th</sup> bred 6 <sup>th</sup> Sep <sup>r</sup> is not common.
NOTES: see Fig. 4. Duplicate figures by Abbot were reproduced for Plate 25 of Boisduval & Le Conte (1829–[1837]). This species feeds on mistletoes ( <i>Phoradendron</i> sp.) (Viscaceae), which are common hemi-parasites of oaks. The depicted larva is a duplicate of the larva that he figured in drawings of <i>Satyrium favonius</i> (J. E. Smith) (see text). It is inconsistent with the "swollen" larva of <i>A. halesus</i> .			
32	<i>Parrhasius m-album</i> (Boisduval & Le Conte)  Dm, Df, Vm, La, Pa	<i>Astragalus michauxii</i> (Kuntze)F. J. Herm. (Fabaceae) [E?]  "Oaks" ( <i>Quercus</i> sp.) (Fagaceae) are confirmed hostplants.	32. Small purple hair Streak Butterfly. Feeds on the Astragalus, and Oaks, changed 20 <sup>th</sup> Aug <sup>t</sup> bred 5 <sup>th</sup> Sep <sup>r</sup> may be met with in different parts of the County. but is rare in all.
NOTES: duplicate figures by Abbot were reproduced for Plate 27 of Boisduval & Le Conte (1829–[1837]). The figured plant may be an erroneous host for this oak-feeder, which has also been dubiously reported to feed on other legumes. Scudder (1888–1889) identified the plant in a duplicate drawing as <i>Astragalus canadensis</i> L. (Fabaceae).			
33	<i>Calycopis cecrops</i> (Fabricius)  Dm, Df, Vm, Lu, Pa	<i>Vaccinium corymbosum</i> L. (Ericaceae) [NC]  "Large black Huckleberry" apparently refers to the depicted plant, but the same plant is portrayed in drawing 36 under a different name.	33. Least purple hair Streak Butterfly. Feeds on the large black Huckleberry, changed 30 <sup>th</sup> April, bred 20 <sup>th</sup> May is frequent in most parts of the Country.
NOTES: a duplicate drawing was reproduced in ATLET (1983). The plant in a duplicate drawing was identified in ATLET (1983) as <i>Gaylussacia frondosa</i> (L.) Torrey & A. Gray ex Torrey) (Ericaceae). The larva of this species is not green as illustrated, but brown or pinkish-brown.			
34	<i>Strymon melinus</i> (Hübner)  Dm, Df, Vm, La, Pa	<i>Hypericum myrtifolium</i> Lam. (Clusiaceae) [C]  "Pines" ( <i>Pinus</i> sp.) (Pinaceae) and "snap beans" (prob. <i>Phaseolus vulgaris</i> L.) (Fabaceae) are confirmed hostplants.	34. Red spotted hair streak Butterfly. Feeds on the flower figured, Pines, snap beans &c. changed 30 <sup>th</sup> April bred 14 <sup>th</sup> May. is not very common.
NOTES: duplicate figures by Abbot were reproduced for Plate 28 of Boisduval & Le Conte (1829–[1837]). These authors identified the plant in their duplicate drawing as a <i>Hypericum</i> , hence the name they proposed for this butterfly, <i>Thecla hyperici</i> .			

TABLE I. Continued

Drawing No.	Figured adults and early stages	Plant species and host status	Manuscript entry by J. Abbot
35	<i>Satyrium liparops</i> (Le Conte)  Dm, Df, La, Pa	<i>Crataegus</i> sp., possibly <i>C. viridis</i> L. (Rosaceae) [C]  "Parsley Haw" refers to <i>Crataegus</i> .	35. Ogechee brown hair steak Butterfly. Feeds on the Parsley Haw, changed 18 <sup>th</sup> April, bred 5 <sup>th</sup> May, This species frequents the Oak woods on the sides of Ogechee river swamp, but is very rare.

NOTES: unlike his other butterfly compositions, the ventral surface of the adult is not portrayed. Another drawing by Abbot was reproduced on Plate 31 of Boisduval & Le Conte (1829–[1837]) to accompany the original description of this species, which remained poorly understood for over a century (See Calhoun 2004, 2005). "Ogechee" is a misspelled reference to the occurrence of this species in the vicinity of the Ogechee River of eastern Georgia.

36	<i>Callophrys henrici</i> (Grote & Robinson)  Dm, Df, Vm, La, Pa	<i>Vaccinium corymbosum</i> L. (Ericaceae) [C]  "Swamp Huckleberry" probably refers to the figured <i>Vaccinium</i> , but the same plant is portrayed in drawing 33 under a different name. "Judas tree" refers to redbud ( <i>Cercis canadensis</i> L.) (Fabaceae). The adults that Abbot saw frequenting the blossoms of redbud may have included ovipositing females, as this tree is also a confirmed hostplant. "Wild plum" ( <i>Prunus</i> sp.) (Rosaceae) is also a confirmed hostplant.	36. Swamp brown hair streak Butterfly. Feeds on the Swamp Huckleberry, changed 20 <sup>th</sup> April, bred 6 <sup>th</sup> May, frequents the blossoms of the Judas tree, and wild plums, on the sides of swamps, is far from common.
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NOTES: duplicate figures by Abbot of the larva and pupa were reproduced for Plate 31 of Boisduval & Le Conte (1829–[1837]). Pupae of this species typically overwinter, but Abbot's notes suggest that his larva developed into an adult during the same season.

37	<i>Callophrys irus</i> (Godart)  Dm, Df, Vf, Lu, Pa	<i>Cyrilla racemiflora</i> L. (Cyrillaceae) (E)	37. Little brown hair streak Butterfly. Feeds on the plant figured &c. changed 22 <sup>d</sup> June, bred 20 <sup>th</sup> March is very rare.
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NOTES: most of a duplicate drawing by Abbot was reproduced for Plate 32 of Boisduval & Le Conte (1829–[1837]) to accompany the original description of *Thecla arsace* Boisduval & Le Conte, now considered a subspecies of *C. irus*. Scott (1986) incorrectly attributed the hostplant association in this composition to *C. henrici*. Gatrell (1999) claimed that Scudder (1888–1889) unsuccessfully attempted to rear *C. henrici* or *C. irus* on *C. racemiflora* as figured, but Scudder actually referred to *Leucothoe racemosa* (L.) A. Gray (Ericaceae). Nonetheless, it is probable that neither of these butterflies would accept *C. racemiflora*, particularly *C. irus*. The illustrated phenotype of this butterfly feeds primarily on species of *Baptisia* (Fabaceae). Although Gatrell (1999) considered the duplicate figure of the larva in Boisduval & Le Conte (1829–[1837]) to be *C. irus*, its shape and coloration are more consistent with *C. henrici*.



2007). Using unpublished and published references, including Allen et al. (2005), Minno et al. (2005), Robinson et al. (2002), and Wagner (2005), I have attempted to evaluate the validity of the associated figures in Abbot's drawings in the Hargrett Library (Table 1). Larvae and pupae were considered "acceptable" if they exhibit fundamental characteristics of the given species.

At least ten of the 32 butterfly drawings in the Hargrett Library (nos. 9, 11, 13, 21, 26, 27, 28, 30, 31, 37) portray erroneous hostplants (Table 1). Two of these emphasize the dubious nature of some of Abbot's compositions. Drawing no. 30 portrays North America's only carnivorous butterfly, *Feniseca tarquinius* (Fabricius). Abbot repeatedly illustrated the larva of this species resting on partially eaten leaves of *Vaccinium arborium* Marshall (Ericaceae) (as in the Hargrett composition), *Viburnum dentatum* L. (Adoxaceae), and *Crataegus* sp. (Rosaceae). He wrote in his accompanying notes that this butterfly most often feeds on alder, *Alnus serrulata* (Aiton) Willd. (Betulaceae). Alder is a common host of woolly alder aphids (*Prociphilus tessellatus* (Fitch)), upon which *F. tarquinius* larvae often feed. Abbot even observed that the larvae were "partly covered with a white loose down," actually a waxy secretion of woolly alder aphids. Entomologists were misled by these drawings until the biology of the species was fully revealed by Edwards (1886). Drawing no. 31 portrays *Atlides halesus* (Cramer) with a sprig of willow oak, *Quercus phellos* (L.) (Fagaceae) (Fig. 4). Although Abbot also referred to this plant in his notes (Table 1), larvae of *A. halesus* feed only on mistletoe (*Phoradendron serotinum* (Raf.) M. C. Johnston) (Viscaceae), which is a common hemi-parasite of oaks in Georgia. Mature larvae of *A. halesus* wander from mistletoe to pupate (Wagner 2005). Abbot probably found larvae of *F. tarquinius* and *A. halesus* on the figured plants and simply assumed that they were the hosts. In addition, the larvae in both of these drawings are inaccurate, suggesting that Abbot illustrated these life histories at a later date. He may have been unable to relocate larvae for his compositions and rendered facsimiles based on the larvae of other species. The larva that he figured in his compositions of *F. tarquinius* is a slightly altered version of the larva that he included in drawings of *Callophrys niphon* (Hübner). His larva of *A. halesus* is a duplicate of the larva that he used for later drawings of *Satyrium favonius* (J. E. Smith). Abbot must have perceived some connection between these butterflies and assumed that their larvae were analogous. Abbot similarly "borrowed" his larva of *Hermeuptychia sosybius* (Fabricius) (no. 20) for his life history

illustrations of *Cyllopsis gemma* (Hübner) (no. 19). He subsequently rendered a new, though inaccurate, replacement larva for *H. sosybius*.

Abbot's illustration of the butterfly *Asterocampa clyton* (Boisduval & Le Conte) (no. 11) is one of the most remarkable examples of his proclivity to invent figures (see Calhoun 2007, Fig. 2). He mistakenly applied the larva and pupa of *A. clyton* to the closely related *Asterocampa celtis* (Boisduval & Le Conte). He fabricated figures for *A. clyton*, modeling them after *Polygonia interrogationis* (Fabricius), another orange butterfly that he found feeding on the same *Celtis* trees (Celtaceae).

Abbot occasionally confused species of Lepidoptera, resulting in erroneous host associations (Calhoun 2006a, 2007). Drawing no. 13 in the Hargrett Library portrays two species of similar butterflies as male and female of the same species. The male is *Phyciodes phaon* (Edwards), while the females are *Phyciodes tharos* (Drury) (Table 1). The larva and pupa are most consistent with *P. tharos*. Larvae of *P. tharos* feed on Asteraceae, thus the depicted plant, *Chrysopsis mariana* (L.) Elliott (Asteraceae), could conceivably serve as a host. On the other hand, *P. phaon* feeds almost exclusively on species of *Phyla* (Verbenaceae).

**Duplication.** Abbot duplicated most of his butterfly life history compositions for 20–25 years (Calhoun 2007). At least 31 of the 32 butterfly drawings in the Hargrett Library are duplicated in other sets of Abbot's illustrations, including the life history drawings that were copied for plates in Boisduval & Le Conte (1829–[1837]) (Table 1). Those original drawings are believed lost, but their notes are deposited in the Houghton Library, Harvard University (Calhoun 2004). I previously attempted to match the entries in the Houghton Library notes with Abbot's drawings that appeared in Boisduval & Le Conte (1829–[1837]) (Calhoun 2004). Lacking other evidence, I tentatively attributed six of these entries solely on the basis of the limited information in the notes. Duplicate drawings and notes that I subsequently discovered in the Hargrett Library were instrumental in confirming my identifications of three of these entries. The Hargrett Library set also shares duplicate figures of adults, larvae, and pupae with other plates in Boisduval & Le Conte (1829–[1837]). These drawings, begun in 1813, are now deposited in the Thomas Cooper Library, University of South Carolina (Calhoun 2004).

**Abbot's observations.** The illustrations and notes of John Abbot represent a valuable window through which we can explore the natural history of Georgia before it was substantially altered by human development. Changes were already affecting the local flora and fauna

during the early nineteenth century (Calhoun 2007). Several of the butterflies portrayed in the Hargrett Library now appear to be less widespread in eastern Georgia than during Abbot's lifetime. These include *Autochton cellus* (Boisduval & Le Conte) (no. 21), *Problema bulenta* (Boisduval & Le Conte) (no. 22), *Euphyes arpa* (Boisduval & Le Conte) (no. 23), *Pyrgus communis* (Grote) (no. 25), and *Erynnis martialis* (Scudder) (no. 27). In fact, *P. bulenta* was suspected of being an imaginary species until it was rediscovered in 1925. *Pyrgus communis* is possibly being displaced in eastern Georgia by the closely related *Pyrgus albescens* (Plötz) (Calhoun 2007).

Abbot was the first to document the life histories of virtually all the species that he illustrated. Many of his drawings were the only available source of this information for over a century. The larva and pupa of *A. cellus* were not observed again until 1934 (Clark 1936). Abbot illustrated *E. martialis* with *Ceonothus americanus* (L.) (Rhamnaceae) over 150 years before Burns (1964) confirmed this association. Although the Hargrett Library drawing of *E. martialis* portrays an erroneous hostplant, Abbot still referred to *C. americanus* in his accompanying notes, calling it "Red root, or red shank." Until very recently, researchers knew nothing about the life history of *Amblyscirtes alternata* (Grote & Robinson) (no. 29). Abbot's unpublished drawings of this species were overlooked because they had been misidentified by Scudder (1872, 1888–1889) and Beirne (1950) as *Amblyscirtes hegon* (Scudder). Although the figured hostplants need confirmation, the early stages in these drawings are consistent with *A. alternata*. Despite his artistic indiscretions, Abbot's illustrations continue to offer precious insight into the natural history of an early Georgia.

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DNA BARCODES OF CLOSELY RELATED (BUT MORPHOLOGICALLY AND ECOLOGICALLY  
DISTINCT) SPECIES OF SKIPPER BUTTERFLIES (HESPERIIDAE) CAN DIFFER  
BY ONLY ONE TO THREE NUCLEOTIDES

JOHN M. BURNS

Department of Entomology, National Museum of Natural History, Smithsonian Institution, P.O. Box 37012, MRC 127, room E-515,  
Washington, DC 20013-7012, USA, email: burnsj@si.edu

DANIEL H. JANZEN

Department of Biology, University of Pennsylvania, Philadelphia, PA 19104, USA, email: djanzen@sas.upenn.edu

MEHRDAD HAJIBABAEI

Department of Integrative Biology, University of Guelph, Guelph, ON, Canada N1G 2W1, email: mhajibab@uoguelph.ca

WINNIE HALLWACHS

Department of Biology, University of Pennsylvania, Philadelphia, PA 19104, USA, email: whallwac@sas.upenn.edu

AND

PAUL D. N. HEBERT

Department of Integrative Biology, University of Guelph, Guelph, ON, Canada N1G 2W1, email: phebert@uoguelph.ca

**ABSTRACT.** Unlike most species of Lepidoptera whose DNA barcodes have been examined, closely related taxa in each of three pairs of hesperiids (*Polyctor cleta* and *P. polyctor*, *Cobalus virbius* and *C. fidicula*, *Neoxeniades luda* and *N. pluviasilva* Burns, new species) seem indistinguishable by their barcodes; but that is when some of the cytochrome *c* oxidase I (COI) sequences are short and sample sizes are small. These skipper butterflies are unquestionably distinct species, as evidenced by genitalic and facies differences and by ecologic segregation, i.e., one species of each pair in dry forest, the other in adjacent rain forest in Area de Conservación Guanacaste in northwestern Costa Rica. This national park is the source of the specimens used in this study, all of which were reared. Larval foodplants are of no or problematic value in distinguishing these species. Large samples of individuals whose barcodes are acceptably long reveal slight interspecific differentiation (involving just one to three nucleotides) in all three pairs of skippers. Clearly, the chronic practice of various taxonomists of setting arbitrary levels of differentiation for delimiting species is unrealistic.

**Additional key words:** Area de Conservación Guanacaste, Costa Rica, dry forest, rain forest, foodplants, genitalia, *Neoxeniades pluviasilva* Burns, n. sp.

A DNA barcode is the base pair (bp) sequence of a short (~650 bp), standard segment of the genome (Hebert *et al.* 2003). In animals, this is part of the mitochondrial gene cytochrome *c* oxidase I (COI). Because the COI gene generally mutates at evolutionarily rapid rates, comparison of barcodes in a sample of individuals best reveals differentiation at low taxonomic levels. Hence barcodes can be extremely useful in distinguishing and identifying species. Coupling this concept with the idea of always comparing the same short length of COI across a wide diversity of taxonomic groups—and doing so with demonstrable success—is what led to the catchy name “DNA barcodes” (Hebert *et al.* 2003). Even though COI had been used effectively in various evolutionary

and taxonomic studies at and around the species level well before this epithet appeared, in the few years since its introduction, barcodes have been used for their specific purpose with notable results and with rapidly increasing frequency.

The rearing of myriad wild-caught caterpillars in Area de Conservación Guanacaste (ACG) in northwestern Costa Rica is now approaching its thirtieth year (for information about both site and rearing process, see Miller *et al.* 2006, Janzen & Hallwachs 2006, Burns & Janzen 2001). DNA barcodes (of a total of 4,260 reared adults) have been able to distinguish among almost 98% of 521 previously known species of the lepidopteran families HesperIIDae (skipper butterflies), Sphingidae (sphinx moths), and Saturniidae (wild silk moths)

(Hajibabaei *et al.* 2006, Janzen *et al.* 2005). Rare cases where barcodes failed, which always involved closely related congeners, are worth examining in more detail. In this paper we treat three such pairs of congeneric skipper species (noted in Hajibabaei *et al.* 2006:table 1). We map the ecologic separation of the species in each pair in and very near ACG. We document the species status of each member of a pair (and describe one as new) on morphologic grounds. We discuss the various degrees to which larval diets, although specialized, are unreliable for species discrimination. And we show, by scrutinizing sequence length and composition, that DNA barcodes separate the species after all. Despite the immense value of DNA barcodes and the fact that they have often indicated overlooked species, it is important to consider characters besides the barcodes themselves—a point made repeatedly in the revelation of 10 cryptic species hiding under the one name *Astraptes fulgerator* (Walch) in ACG (Hebert *et al.* 2004).

THE SPECIES PAIRS IN QUESTION

**Ecologic separation (Figs. 1-3).** Each pair comprises a dry-forest species and a rainforest species. Parapatry of this kind is a recurrent distribution pattern among closely related lepidopteran species in ACG. In each pair of the following list, the dry-forest species comes first: *Polyctor cleta* Evans and *P. polyctor* (Prittwitz), *Cobalus virbius* (Cramer) and *C. fidicula* (Hewitson), *Neoxeniades luda* (Hewitson) and *N. pluviasilva* Burns (a new species described below). *Polyctor* is a pyrgine genus, and *Cobalus* and *Neoxeniades* are hesperiine genera.

From our distribution data, parapatry in both pairs of hesperiine species appears to be complete (Figs. 2, 3) whereas that in the pyrgine pair does not (Fig. 1). Out of 211 reared individuals (wild-caught as caterpillars) of the rainforest species *P. polyctor*, four came from dry forest. The genitalia of these apparent strays have been KOH-dissected and thoroughly studied to be sure of

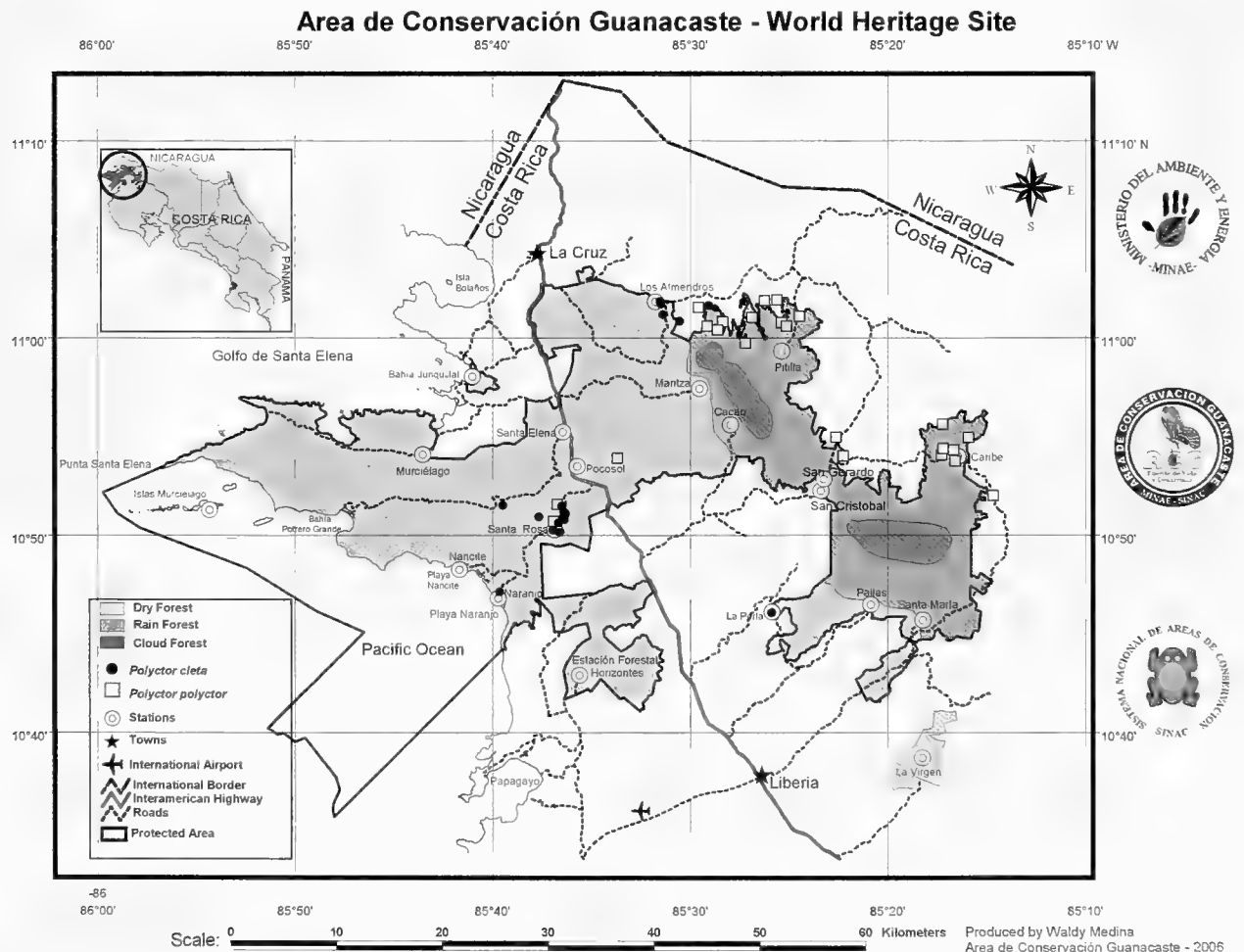


FIG. 1. Spatial distribution of *Polyctor cleta* and *P. polyctor* in and near ACG.

their specific determination. Because both species of this essentially parapatric pair of *Polyctor* eat the same three species of foodplants (Table 3), and because one of these plants occurs in both rain and dry forest, a female wandering from rain forest can find an attractive foodplant in dry forest and oviposit on it. The flight of these skippers is far stronger than necessary to travel the distance involved. Of the four *P. polyctor* caterpillars found in dry forest, three were eating the species of foodplant most often eaten by this skipper in rain forest (and because two of those were found on the very same plant, they are probably offspring of a single female); the fourth caterpillar was eating an exceedingly common, but strictly dry-forest, species that is by far the preferred foodplant of *P. cleta*.

A small number of *P. cleta* caterpillars found in disturbed ecotone between dry and rain forest, and less than 2 km from the latter, were eating the main foodplant of *P. polyctor*. KOH-dissection and examination of the genitalia of the four adults reared

from this group gave no hint of hybridization.

**Morphologic differences (Figs. 4-41; Tables 1, 2).**

In all three pairs, the brown ground color of the adult averages paler in the dry-forest species than it does in its rainforest counterpart (Figs. 4-27). This is especially evident when comparing long series of more or less recently reared (therefore unfaded) specimens.

In both sexes of *Polyctor*, a spot spanning the distal end of the forewing cell is hyaline in *P. cleta* but opaque in *P. polyctor*. A male secondary sex character in these species of *Polyctor* comprises a tuft of long hairlike scales arising near the base of the dorsal hindwing costa, as well as an elongate patch of pale specialized scales embraced by the swollen beginning of vein 7 and a similarly swollen, closely adjacent length of vein 6; in both veins, swelling extends out to the end of the cell; and the hairlike scales are long enough to overlie the special patch. These presumably pheromone-disseminating hairs are mostly to entirely dark in *P. cleta* but pale (often orangish) in *P. polyctor* (cf. Figs. 4 and 6).

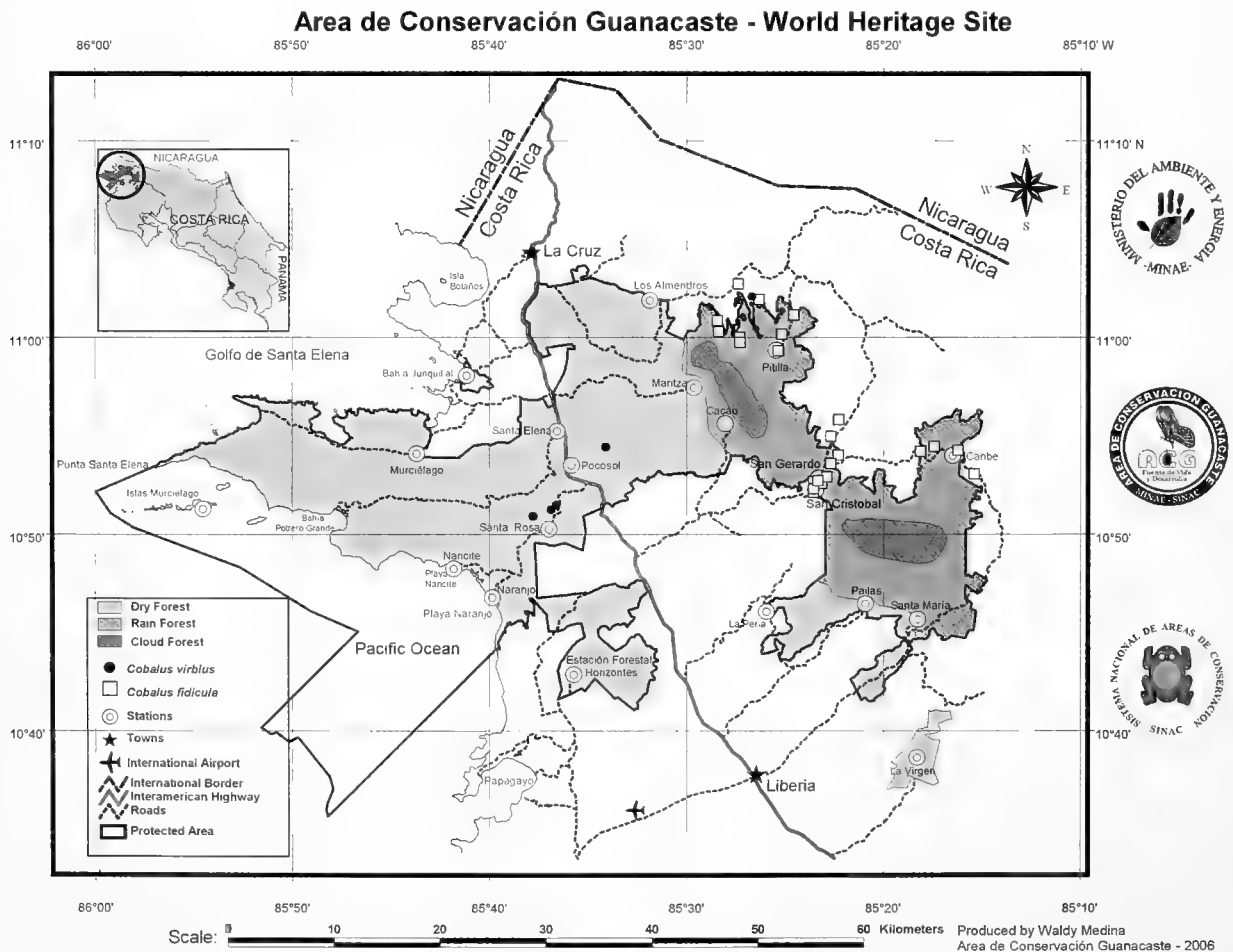


FIG. 2. Spatial distribution of *Cobalus virbius* and *C. fidicula* in and near ACG.



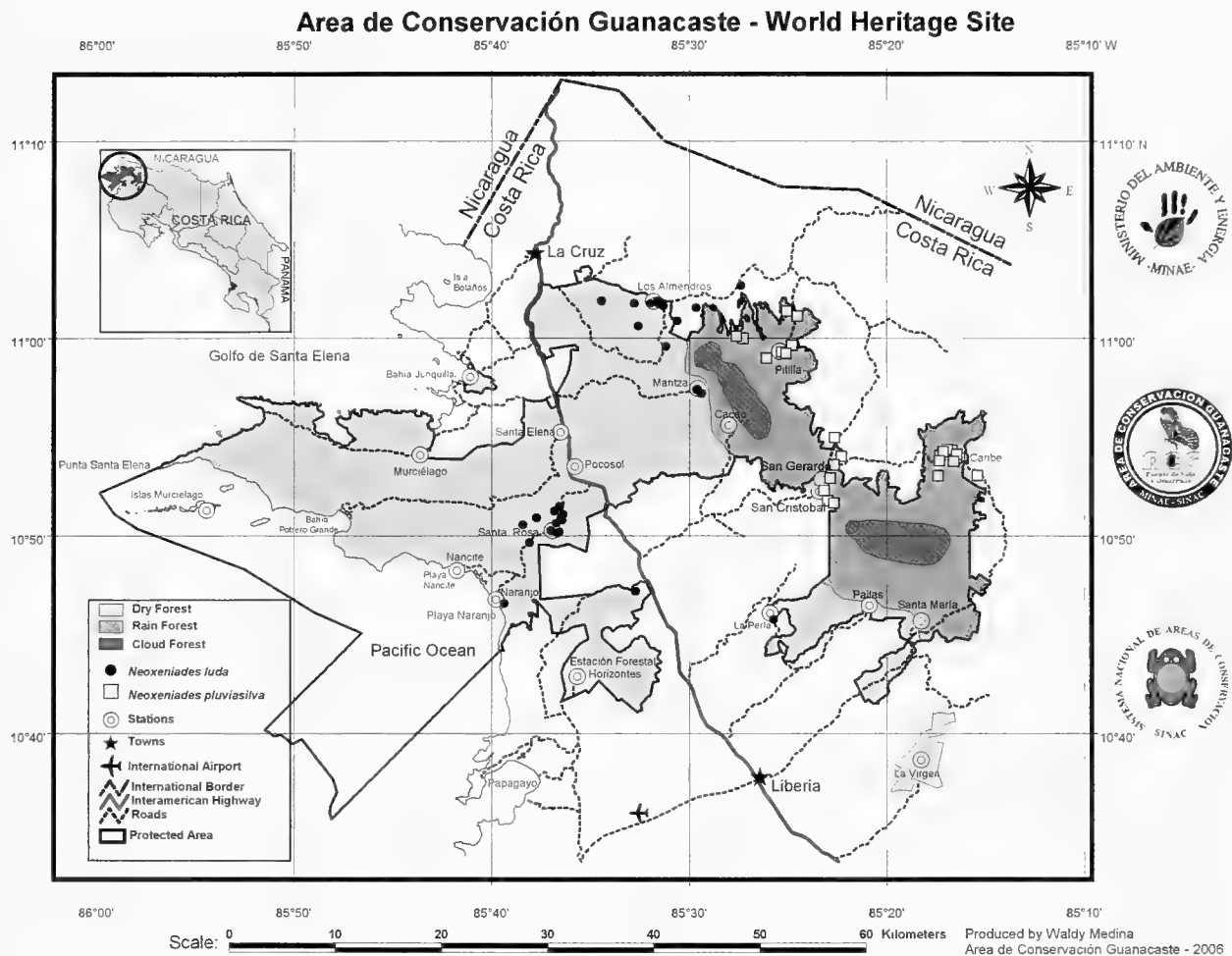


FIG. 3. Spatial distribution of *Neoxeniades luda* and *N. pluviasilva* in and near ACG.

Though clearly variations on a theme, the male genitalia of these two *Polyctor* species differ in striking ways. Despite substantial individual variation, almost every genitalic part differs interspecifically to at least some extent; but it is the highly asymmetric valvae that differ most (see Table 1 and cf. Figs. 28–33). Even the less elaborate female genitalia are notably distinct in the two species (Table 2).

Both species of *Cobalus*, which are predominantly brown, have a conspicuous white patch both dorsally and ventrally on a distal area of the hindwing. In ACG specimens, this patch is restricted to males of *C. fidicula* but expressed by both sexes of *C. virbius* (Figs. 8–11, 20–23), except for two females in which it is barely perceptible. Both species express it more fully ventrally than dorsally. In *C. fidicula* the patch stops before the outer margin so as to leave a narrow strip of dark brown ground color, ventrally the patch extends from mid space 1c to vein 6, and the white of the patch looks creamy on the ventral surface. In *C. virbius* the patch

reaches the outer margin, ventrally extends from the tornus to vein 6, and looks pure white on both wing surfaces. Lateral orange scaling—broad on the outer side of the palpus and narrow behind the eye—is bright in *C. fidicula* but just dully suggested, and only on the palpus, in *C. virbius*. *Cobalus fidicula* is a little larger than *C. virbius*, and its forewing hyaline spots are likewise larger.

The male genitalia (which are symmetric) differ in two obvious respects. The ventral distal division of the valva is longer and dorsally dentate in *C. fidicula* (cf. Figs. 35 and 37). The very broad uncus in dorsal view shows a pair of prominent lateral swellings in *C. virbius* (cf. Figs. 34 and 36).

***Neoxeniades pluviasilva* Burns, new species**  
(Figs. 3, 14, 15, 26, 27, 40, 41, 45, 46; Table 3)

**Etymology.** The species name, a noun in apposition, comes from the Latin *pluvia* for rain and *silva* for forest.

**Diagnosis.** This is a rainforest species whereas

TABLE 1. Major differences between male genitalia of *Polyctor cleta* and *P. polyctor*.

	<i>Polyctor cleta</i>	<i>Polyctor polyctor</i>
LEFT VALVA:		
Curved flap extending inward from dorsal margin	Narrower at base	Wider at base
Distal dorsal division	Not expanded; teeth finer	Expanded; teeth coarser
Distal ventral division	Bent sharply dorsad	Evenly curved dorsad
RIGHT VALVA:		
Distal dorsal division:		
Dentation on edge of	More distal; finer	More dorsal; coarser
SACCUS	More delicate; shorter to about gone	Heavier; longer
UNCUS, dorsally nr. origin	No longitudinal humps	Pair of longitudinal humps

*N. luda* is a species of the dry forest (Fig. 3). At a glance, *N. phuiasilva* is darker than *N. luda* and does not express a large, pale, outer marginal area on the ventral side of the hindwing nearly as well (cf. Figs. 26, 27 with 24, 25). In females of *N. phuiasilva*, the double hyaline cell spot of the forewing extensively overlaps the spot in space 2 whereas in *N. luda* females, this forewing cell spot overlaps the spot in space 2 little or not at all (cf. Figs. 15, 27 with 13, 25).

**Description.** Member, with *N. luda*, of mainly South American *N. scipio* species complex—treated by Evans (1955) as a polytypic species. This complex closely related to type species of *Neoxeniades*, *N. musarion* Hayward of Rio de Janeiro and Petrópolis, Brazil.

**Facies:** Brown ground color dark. Ventral brown ground color sexually dimorphic: warmer and rustier in male (Fig. 26); colder, with purplish gray overscaling, in female (Fig. 27). Sexual dimorphism also pronounced in size of forewing hyaline spots in space 2 and in cell: much larger in female than in male, with spots overlapping one another (cf. Figs. 15, 27 with Figs. 14, 26) [no such pronounced sexual dimorphisms in *N. luda* (Figs. 12, 13, 24, 25)]. Large, outer marginal, pale patch on ventral hindwing inconspicuous in male (Fig. 26) to all but nonexistent in female (Fig. 27) [patch always obvious in both sexes of *N. luda* (Figs. 24, 25)]. Dorsally, male always showing hyaline spot in space 1b just above mid vein 1, but spot almost always small (Fig. 14) to tiny. Female, more often than not, lacking this spot dorsally; but spot, when showing, usually tiny (Fig. 15). [In *N. luda*, male always with this spot, and spot usually well-expressed (Fig. 12); about two-thirds of females with this spot which, when present, more often small (Fig. 13) than tiny.]

**Male genitalia:** Symmetric; short anterior edge of slightly raised, dorsally dentate, distal end of valva curved somewhat cephalad in lateral view (Fig. 41) [about straight to curved somewhat caudad in lateral view (Fig. 39) in *N. luda*].

**Female genitalia:** Immediately anterior to papillae anales, sclerotized transverse plate of lamella postvaginalis with broad, rounded midventral elevation [narrower, more pointed in *N. luda*].

**Type specimens:** *Holotype:* male (Figs. 14, 26, 45, 46 [see arrow]), voucher code 06-SRNP-31674 (Janzen & Hallwachs 2006), Sendero Memos, Sector Pitilla, Area de Conservación Guanacaste, Costa Rica, 740 m, latitude 10.98171, longitude -85.42785. Deposition: National Museum of Natural History, Smithsonian Institution (USNM). Labelled (yellow): LEGS AWAY/FOR DNA. DNA barcode (658 bp) of holotype (coded MHAHH575-06106-SRNP-31674#*Neoxeniades phuiasilva*):

AACTTTATACTTTATTTTTGGAAATTTGAGCAGGAATATTAGG  
AACTTCATTAAGTTTATTAATCCGTACAGAATTTGGGAAATCCAG  
GATTTTTAATTGGAAATGATCAAAATTTCAAGAAATTTGTACAG  
CTCATGCATTTATTATAATTTTTTTTATAGTTATACCTATTATAAT  
TGGAGGATTTGGAAATTTGATTAGTACCTTTAATATTAGGAGCT  
CCAGATATAGCTTTCCCTCGAATAAATAAATAGATTTTGATTA  
TTACCTCCTTCTTTAATAATCTTTAATTTCAAGAAATTTGTAGAGA  
AAATGGAGCTGGCACTGGATGAACTGTTTATCCCCCTCTTTTC  
CTTAACATTTGCTCATCAAGGATCATCTGTAGATTTAGCAATCT  
TCTCACTCCATCTAGCTGGAATTTTCACTATTTTAGGAGCTATT  
AATTTTATACCAGAAATTTAATATGCGAATAAATAAATTTATCTT  
TTGATCAAATATCTTTATTCCTGTGATCTGTTGGTATTACTGCT  
TTACTTTTACTCTTATCTTACCAGTCTTAGCTGGAGTATGAC  
AATATTACTTACTGACCGAAATCTTAATACTTCTTTTTTCGACC  
CAGCAGGAGGAGGAGATCTTATTTATATCAACATTTATTT

*Paratypes:* 14 males, 19 females, ACG, Costa Rica (USNM).

The lone synonym of *N. luda* is *Proteides hundurensis* Mabille. Mabille's (1891) original description of one female from Honduras clearly applies to *N. luda*.

**Foodplants:** Larval foodplants of this rainforest skipper at least eight species in five genera (one introduced) of Bromeliaceae (Table 3) [no known overlap in foodplant use at species level with dry-forest, sister species *N. luda*; but one overlap at genus level].

**Larval foodplants (Table 3).** Foodplants do not distinguish sister species of the pyrgine genus *Polyctor*: both of these skippers eat one and the same plant species in each of three genera (*Allenanthus*, *Coutarea*, and *Exostema*) of the family Rubiaceae. Nevertheless, *P. cleta* and *P. polyctor* use these plants at very different frequencies. Although this may reflect different preferences of the skippers, it more likely stems from the different ecologic distributions of the foodplants: *Coutarea hexandra* occurs at low frequency in both rain and dry forest, *A. erythrocarpus* is a rainforest plant

TABLE 2. Major differences between female genitalia of *Polyctor cleta* and *P. polyctor*.

	<i>Polyctor cleta</i>	<i>Polyctor polyctor</i>
Sclerotized sterigmal area	Smaller	Larger
Overall asymmetry	Not extreme	Pronounced
Sclerotized flap on right side of sterigma	Absent or small	Very large
Sclerotized ostium bursae	Conspicuously projecting (tube-like) from surface of sterigma	Relatively flush with surface of sterigma

TABLE 3. Larval foodplants of two species of *Polyctor*, *Cobalus*, and *Neoxeniades* in Area de Conservación Guanacaste, northwestern Costa Rica; the number of rearing records for each plant species is given (source, Janzen & Hallwachs 2006).

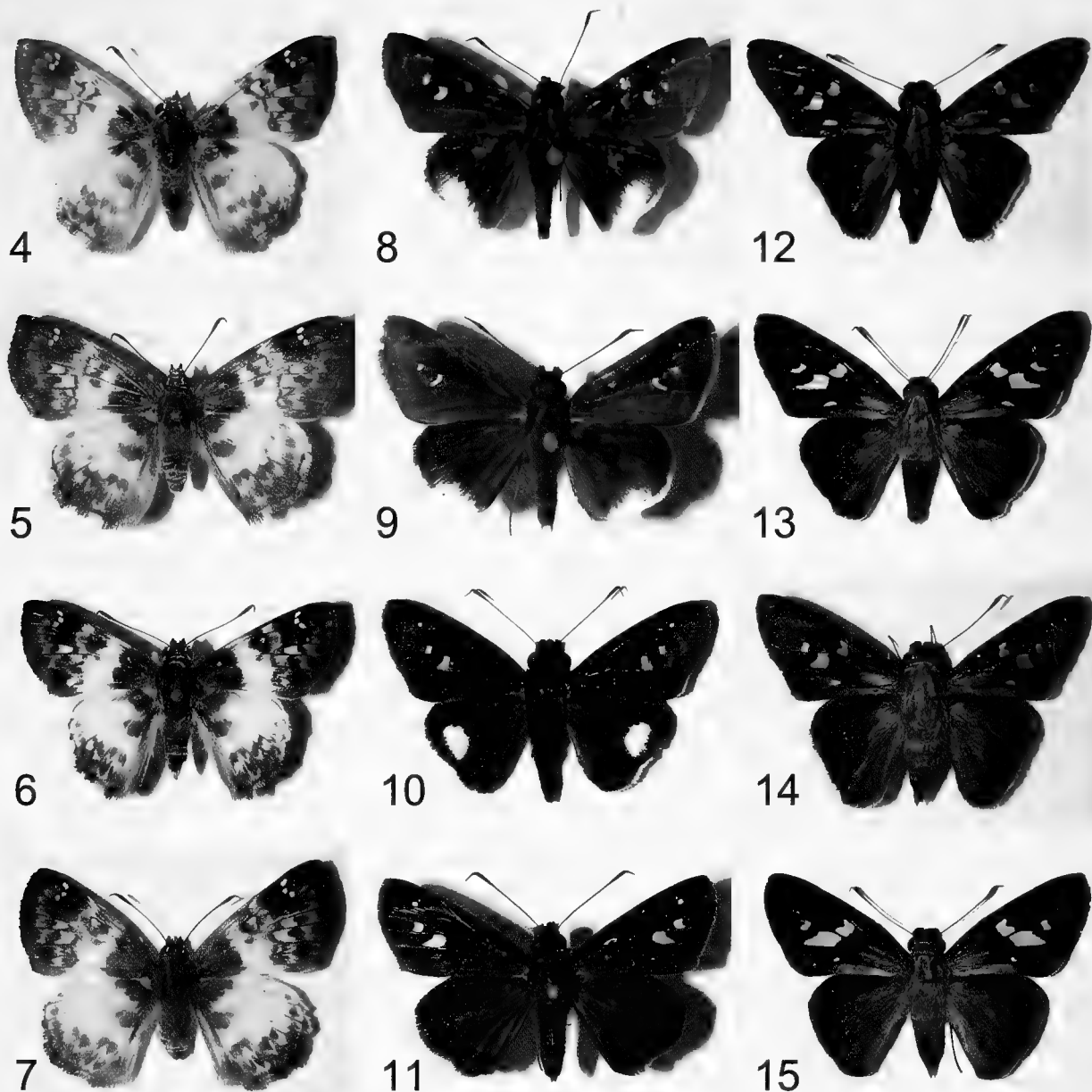
<b><i>Polyctor cleta</i></b>		
Rubiaceae		
	<i>Allenanthus erythrocarpus</i>	9
	<i>Coutarea hexandra</i>	7
	<i>Exostema caribaeum</i>	1
	<i>Exostema mexicanum</i>	124
<b><i>Polyctor polyctor</i></b>		
Rubiaceae		
	<i>Allenanthus erythrocarpus</i>	44
	<i>Coutarea hexandra</i>	166
	<i>Exostema mexicanum</i>	1
<b><i>Cobalus virbius</i></b>		
Arecaceae		
	<i>Acrocomia aculeata</i>	7
	<i>Bactris guineensis</i>	5
<b><i>Cobalus fidicula</i></b>		
Arecaceae		
	<i>Astrocaryum alatum</i>	25
	<i>Bactris gasipaes</i> (introduced)	5
	<i>Bactris gracilior</i>	6
	<i>Bactris hondurensis</i>	10
	<i>Chamaedorea dammeriana</i>	1
	<i>Chamaedorea pinnatifrons</i>	1
	<i>Cryosophila warscewiczii</i>	1
	<i>Prestoea decurrens</i>	1
<b><i>Neoxeniades luda</i></b>		
Bromeliaceae		
	<i>Aechmea bracteata</i>	4
	<i>Aechmea magdalenae</i>	30
	<i>Bromelia pinguin</i>	138
<b><i>Neoxeniades pluviasilva</i></b>		
Bromeliaceae		
	<i>Aechmea pubescens</i>	12
	<i>Ananas comosus</i> (introduced)	3
	<i>Guzmania desautelsii</i>	3
	<i>Guzmania donnellsmithii</i>	12
	<i>Guzmania nicaraguensis</i>	1
	<i>Pitcairnia arcuata</i>	1
	<i>Pitcairnia atrorubens</i>	4
	<i>Vriesea gladioliflora</i>	19

(used by *P. cleta* at the very edge of the dry forest/rain forest ecotone), and *E. mexicanum* is a common dry-forest plant (used once by a *P. polyctor* that apparently strayed some 15 km from rain forest).

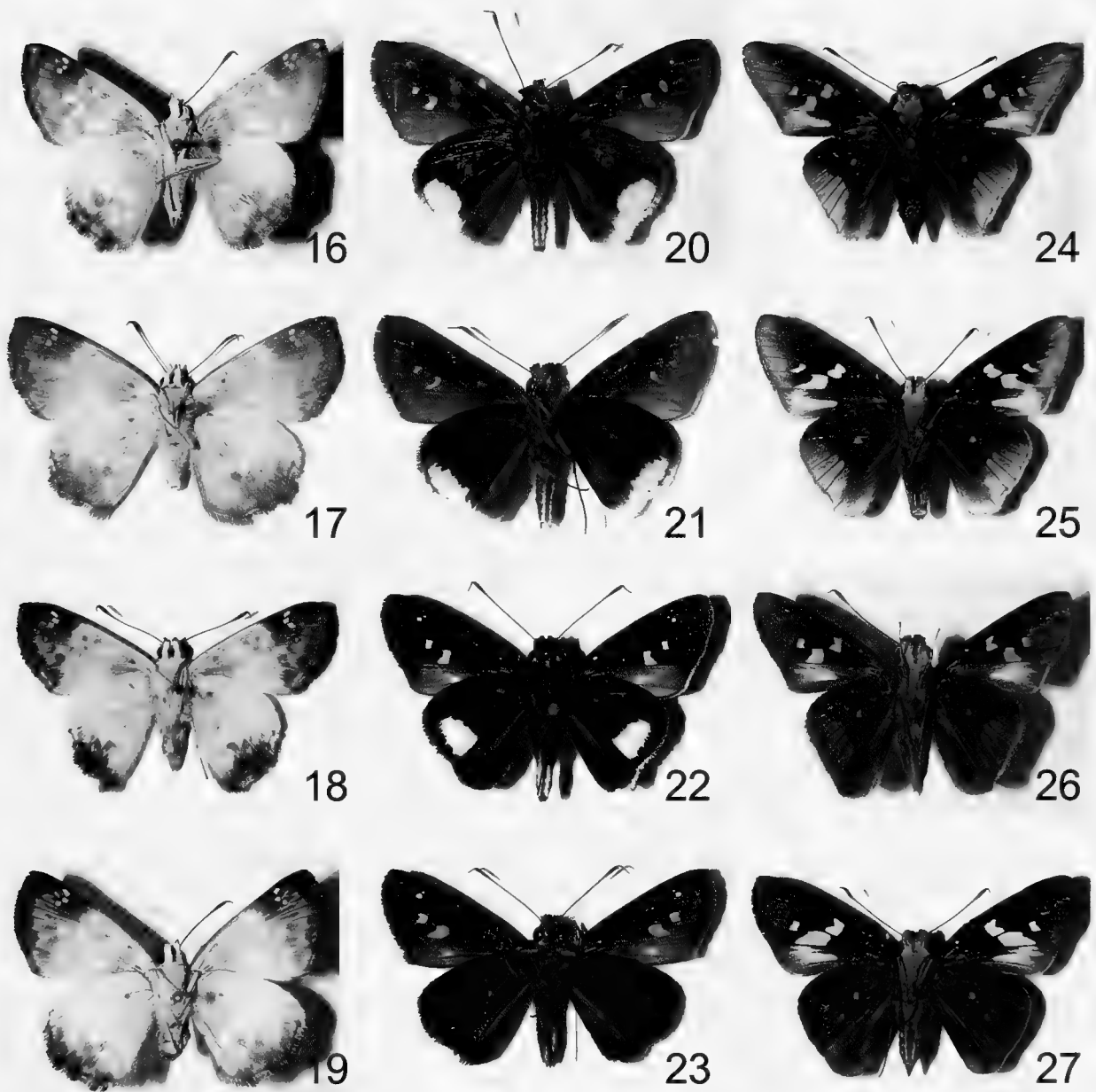
Conversely, foodplants do seem to distinguish the species of the species pairs in the hesperiine genera *Cobalus* and *Neoxeniades*. In each pair, the rainforest skipper feeds on more species than its dry-forest counterpart. *Cobalus virbius* eats two plant species in two genera, and *C. fidicula* eight plant species in five genera, of the family Arecaceae (palms). *Neoxeniades luda* eats three plant species in two genera, and *N. pluviasilva* eight plant species in five genera, of the family Bromeliaceae (bromeliads). The species in each skipper pair share no foodplant species and just one genus. However, these considerable differences in diet may have little taxonomic significance. Palms and bromeliads are far more diverse in rain forest than they are in dry forest, so that the rainforest skippers have a wider choice. Were either species of a pair to invade the other's ecosystem, it might well find its relative's foodplants acceptable. This conjecture is somewhat weakened by the fact that the rainforest skippers, though polyphagous, still restrict their diet to fewer species of palms and bromeliads than are available to them; and even one dry-forest species is somewhat choosy. To illustrate, the ACG dry forest provides only two species of palms for *C. virbius*, both of which it eats, whereas the rain forest offers >10 species of palms beyond the eight so far recorded for *C. fidicula*. The dry-forest skipper *N. luda* eats the three terrestrial bromeliad species, but not the epiphytic ones, available to it, whereas *N. pluviasilva* eats both kinds of bromeliads, but seems nevertheless to ignore many of the epiphytic species at hand.

**DNA barcodes (Figs. 42–46).** For our barcoding methods, see Hajibabaei *et al.* (2006:971). We determined sequence divergences among individuals in each species pair (as well as in a related outgroup species) by means of the Kimura-2-Parameter (K2P) distance model (Kimura 1980), and then showed these divergences in neighbor-joining (NJ) trees (Saitou & Nei 1987). A paper in preparation will deposit in GenBank all of the sequences used here (along with thousands more for hundreds of species in various lepidopteran families, including Hesperidae). All voucher specimens have been deposited in the National Museum of Natural History, Smithsonian Institution.

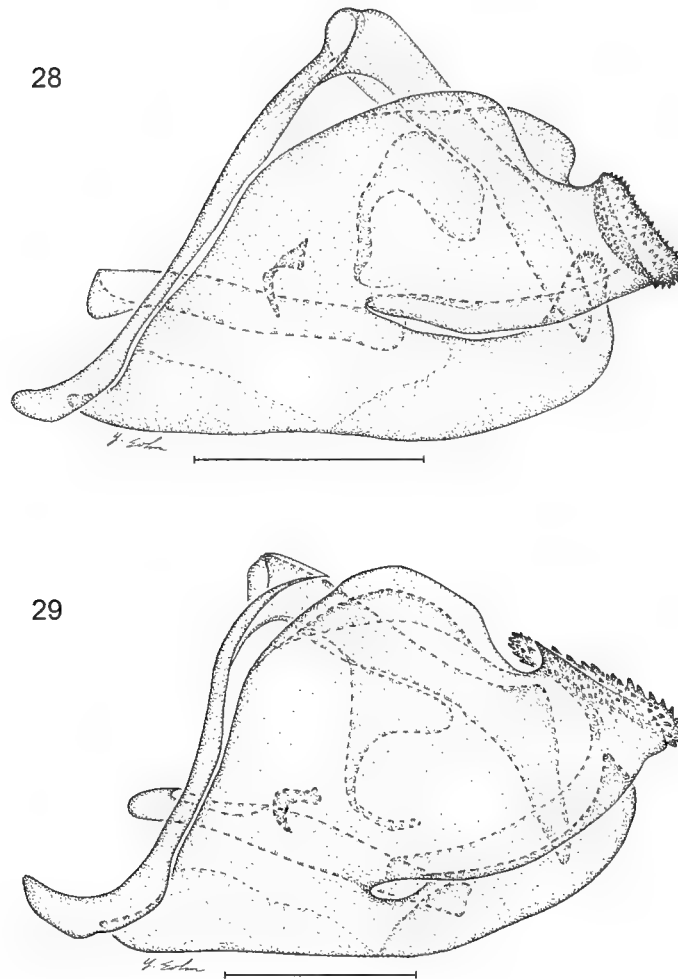
Since we could not discriminate between the species in each pair during our early barcoding efforts, we greatly increased sample sizes; but we still included some COI sequences that were too short to qualify as legitimate barcodes. Two of the resulting NJ trees



FIGS. 4–15. Reared adults in dorsal view of *Polyctor*, *Cobalus*, and *Neoxeniades* from ACG, Costa Rica (specimens in USNM). Males even-numbered, females odd-numbered. Wingspan and voucher code given for each specimen. **4, 5**, *P. cleta*: 32 mm, 02-SRNP-32285; 40 mm, 06-SRNP-869. **6, 7**, *P. polyctor*: 35 mm, 05-SRNP-42248; 34 mm, 03-SRNP-9639. **8, 9**, *C. virbius*: 32 mm, 92-SRNP-6215.1; 32 mm, 92-SRNP-46. **10, 11**, *C. fidicula*: 39 mm, 05-SRNP-23068; 36 mm, 04-SRNP-32408. **12, 13**, *N. luda*: 49 mm, 01-SRNP-11651; 53 mm, 03-SRNP-38341. **14, 15**, *N. pluviasilva*: 43 mm, 06-SRNP-31674; 52 mm, 05-SRNP-22927.



FIGS. 16–27. Reared adults in ventral view of *Polyctor*, *Cobalus*, and *Neoxeniades* from ACG, Costa Rica (specimens in USNM). Males even-numbered, females odd-numbered. Same specimens in same sequence as in Figs. 4–15. 16, 17, *P. cleta*. 18, 19, *P. polyctor*. 20, 21, *C. virbius*. 22, 23, *C. fidicula*. 24, 25, *N. luda*. 26, 27, *N. pluviasilva*.



FIGS. 28, 29. Asymmetric male genitalia in left lateral view of two species of *Polyctor* from ACC, Costa Rica (USNM), scale = 1.0 mm. **28**, *P. cleta*, genitalia dissection code X-6165, voucher code 03-SRNP-30880. **29**, *P. polyctor*, X-6159, 02-SRNP-7128.

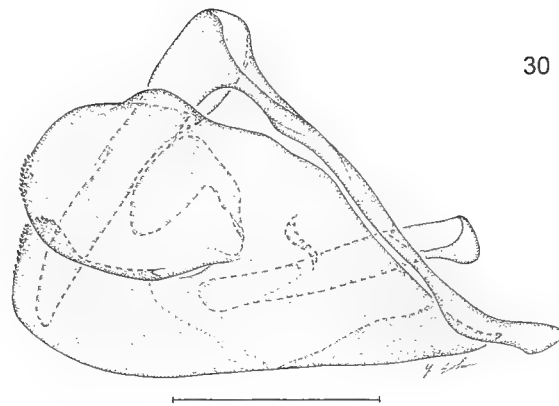
nearly separated the two species of *Polyctor* (Fig. 42) and those of *Cobalus* (Fig. 44). However, the third tree appreciably intermixed the two species of *Neoxeniades* (Fig. 45). The short sequences lacked diagnostic sites and therefore compromised the NJ analysis. Subsequent exclusion of short sequences resulted in clear species separation (Figs. 43, 46).

Close examination of the barcode nucleotides showed that the two species of *Polyctor* consistently differ at three nucleotide positions (610, 616, and 625), and the two species of *Neoxeniades*, at one (115). Similarly, the two species of *Cobalus* differ in one nucleotide (at position 181), except for two females of *C. virbius* (04-SRNP-21798 and 06-SRNP-22664) whose “diagnostic” nucleotide is the same as that of the *C. fidicula* specimens. The two females of *C. virbius* whose

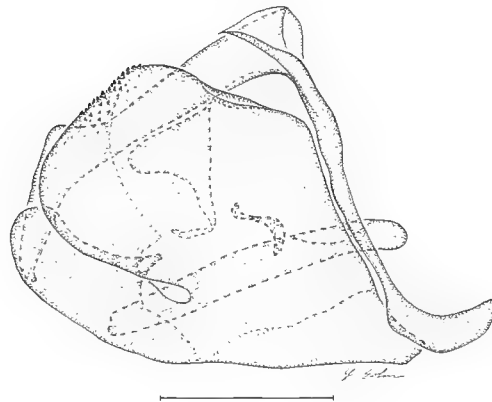
barcodes match those of *C. fidicula* are not the two females of *C. virbius* (noted above, under “Morphologic differences” [with voucher codes 92-SRNP-340 and 06-SRNP-13344]) whose hindwing facies approaches that of *C. fidicula* females. Because, in each pair of skipper species, the interspecific nucleotide differences are very few (compared with many species of skippers previously examined), full-length, high-quality barcode sequences (~650 bp) are critical for distinguishing the species in each pair. Of course, characters of this kind—like many others—may vary geographically.

The levels at which these species are distinguished is so low that, in many other circumstances, their differences could easily qualify as nothing more than individual variation. It follows that the designation of some percentage or degree of divergence as a point



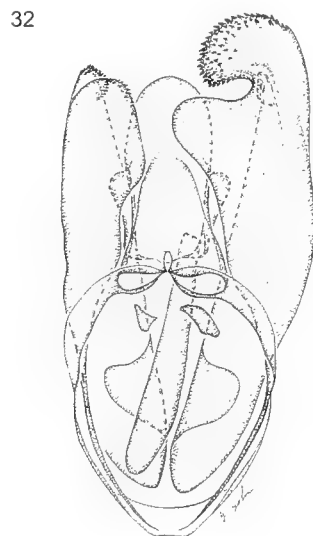


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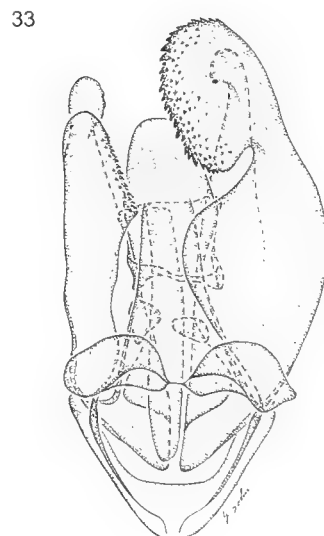


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FIGS. 30, 31. Asymmetric male genitalia in right lateral view of two species of *Polyctor* from ACG, Costa Rica (USNM), scale = 1.0 mm. **30**, *P. cleta*, X-6165, 03-SRNP-30880. **31**, *P. polyctor*, X-6159, 02-SRNP-7128.

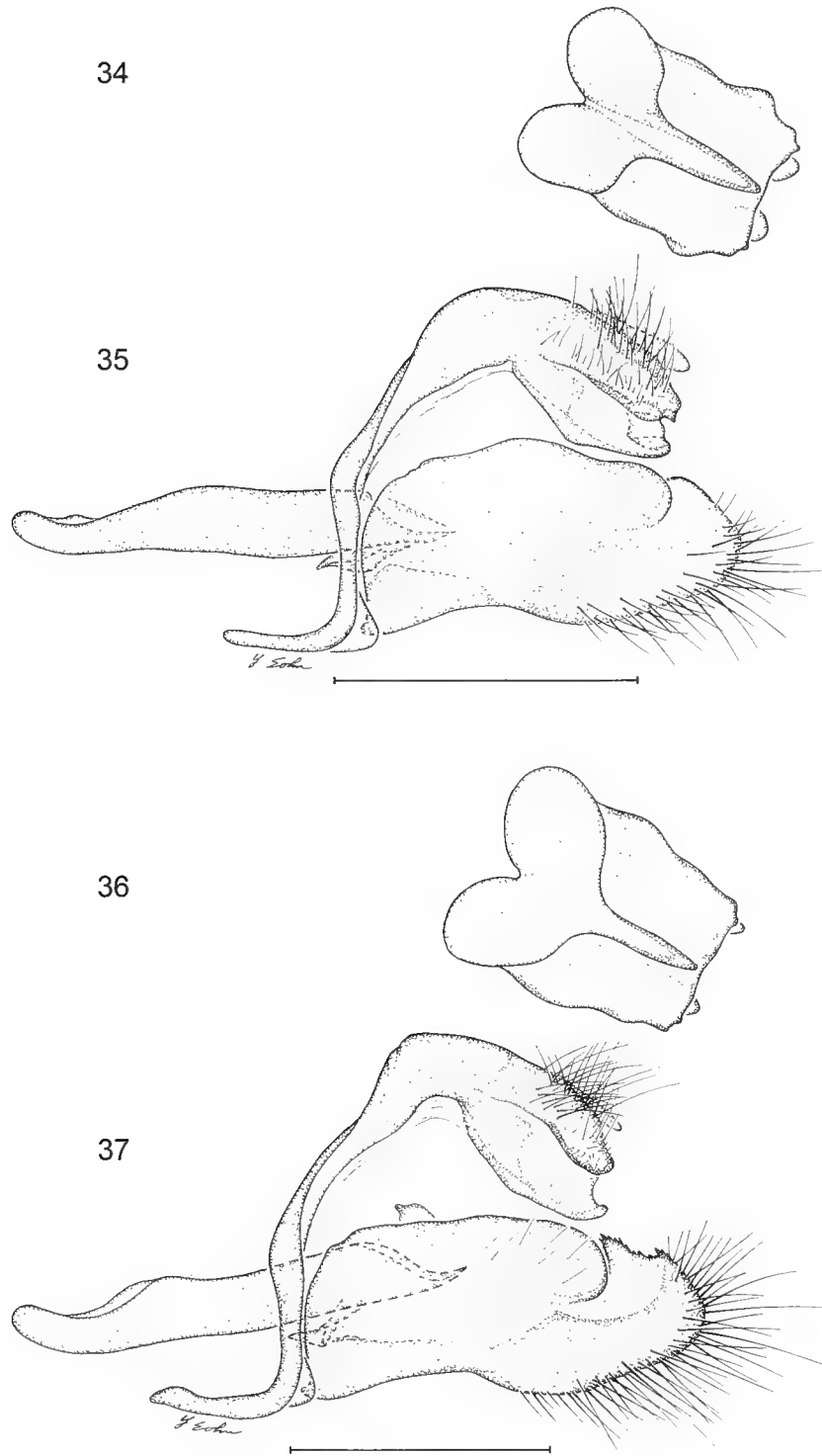


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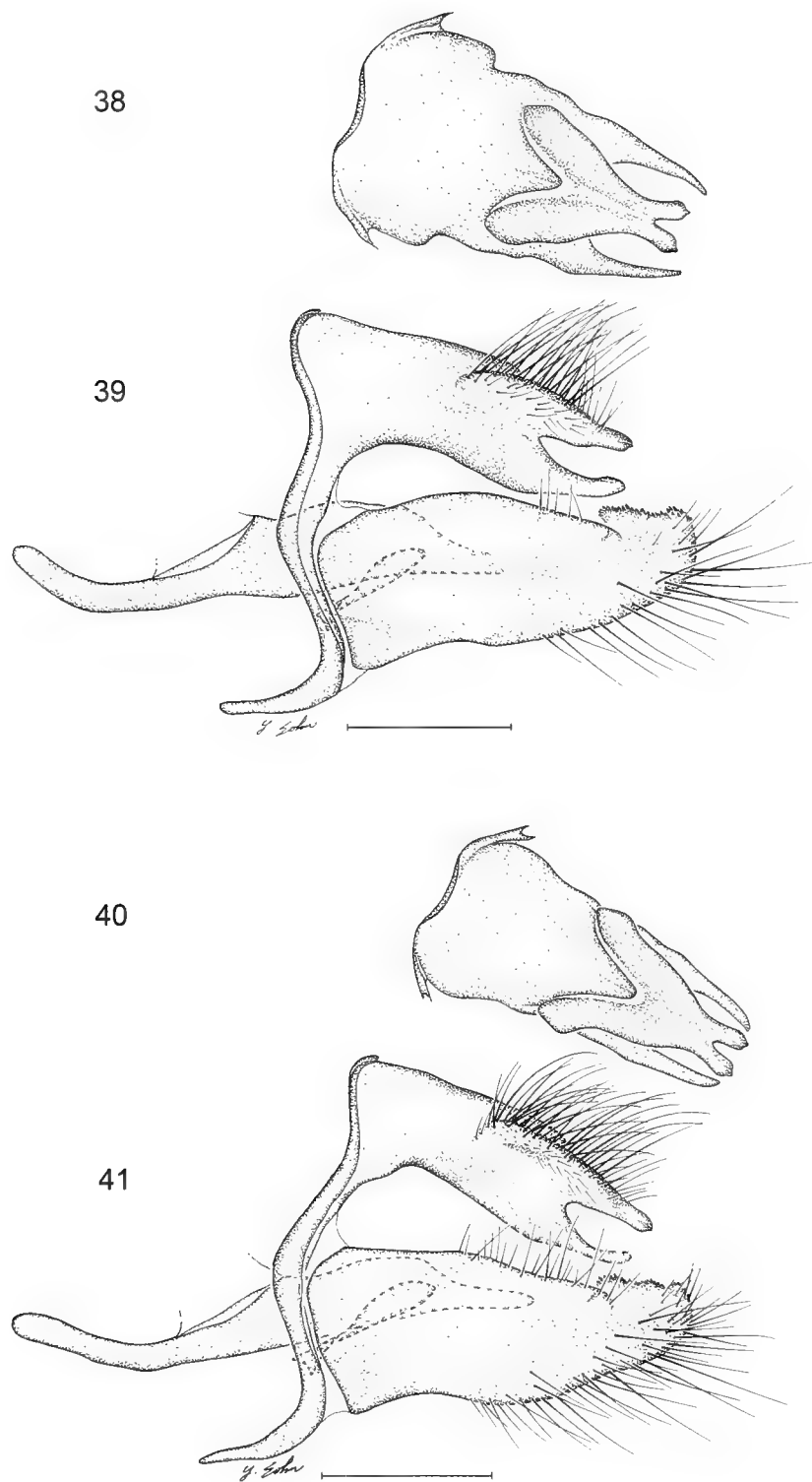


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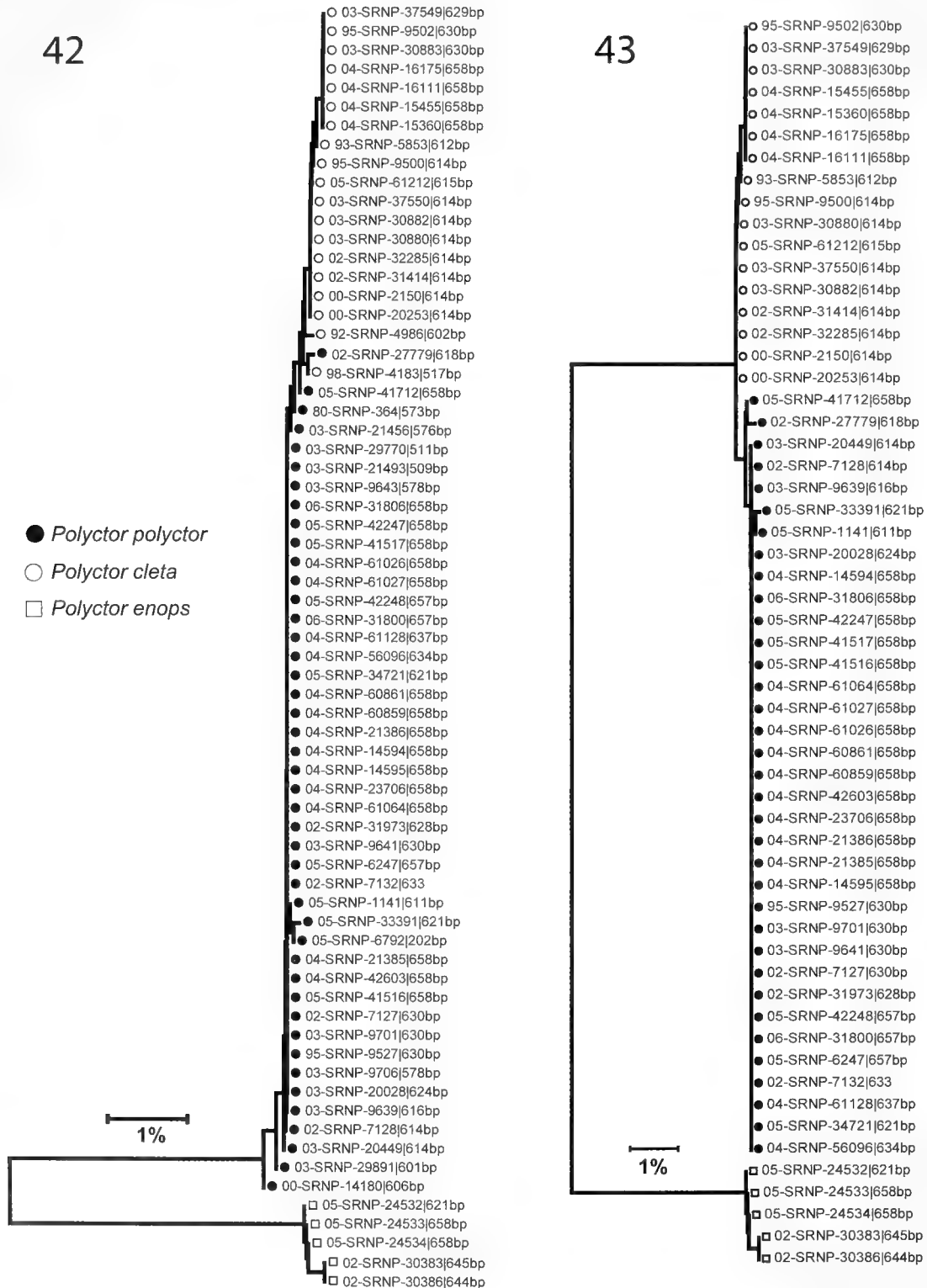
FIGS. 32, 33. Asymmetric male genitalia in dorsal view of two species of *Polyctor* from ACG, Costa Rica (USNM), scale = 1.0 mm. **32**, *P. cleta*, X-6165, 03-SRNP-30880. **33**, *P. polyctor*, X-6159, 02-SRNP-7128.



FIGS. 34–37. Male genitalia of two species of *Cobalus* from ACG, Costa Rica (USNM), scale = 1.0 mm. **34, 35**, *C. virbius*, X-5873, 99-SRNP-6213. **36, 37**, *C. fidicula*, X-5876, 99-SRNP-5803. **34, 36**, Tegumen, uncus, and gnathos in dorsal view. **35, 37**, Complete genitalia in left lateral view.



FIGS. 38–41. Male genitalia of two species of *Neoxeniades* from ACG, Costa Rica (USNM), scale = 1.0 mm. **38, 39**, *N. luda*, X-6372, 95-SRNP-10736. **40, 41**, *N. pluviasilva*, X-5799, 00-SRNP-2211. **38, 40**, Tegumen, uncus, and gnathos in dorsal view. **39, 41**, Complete genitalia in left lateral view.



FIGS. 42, 43. Neighbor-joining (NJ) trees based on Kimura-2-Parameter (K2P) distances for cytochrome *c* oxidase I (COI) of *Polycitor* from ACG, Costa Rica. Outgroup, *P. enops*. Rearing voucher code and sequence length given for each individual. To find the larval foodplant of any individual, enter its voucher code in the ACG database (Janzen & Hallwachs 2006). **42**, 19 *P. cleta* and 44 *P. polyctor* with various COI sequence lengths. **43**, 17 *P. cleta* and 35 *P. polyctor* with COI barcodes of sufficient lengths (approaching or exceeding 650 base pairs) for distinguishing these species.

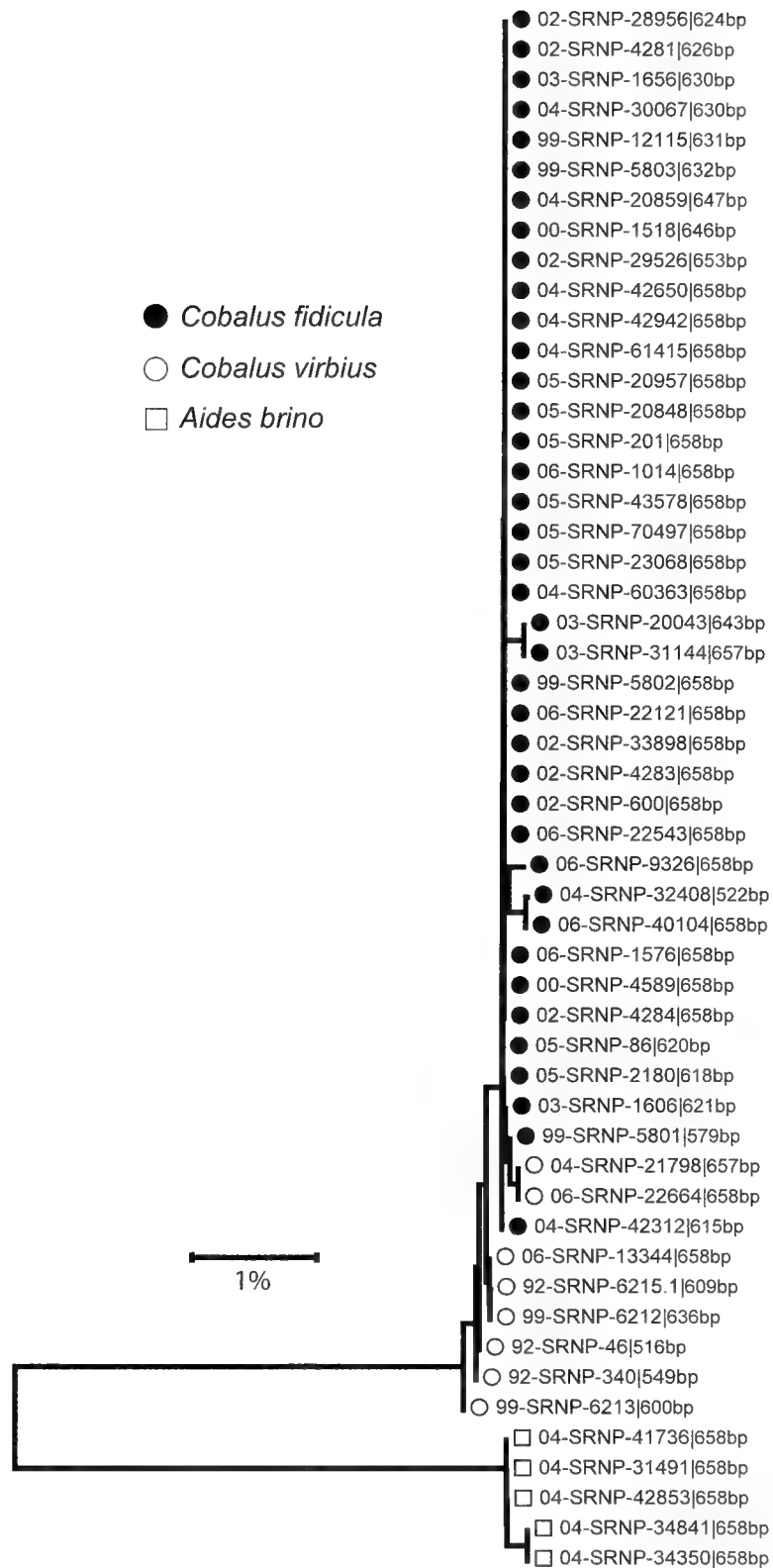


FIG. 44. NJ tree based on K2P distances for COI of 8 *Cobalus virbius* and 39 *C. fidicula* from ACG, Costa Rica. Outgroup, *Aedes brino*. Rearing voucher code and sequence length given for each individual.



FIGS. 45, 46. NJ trees based on K2P distances for COI of *Neoxeniades* from ACC, Costa Rica. Outgroup, *N. BURNS04* (an undescribed species). Rearing voucher code and sequence length given for each individual. Arrow indicates holotype. **45**, 13 *N. luda* and 24 *N. pluviasilva* with various COI sequence lengths. **46**, 7 *N. luda* and 12 *N. pluviasilva* with COI barcodes of sufficient lengths for distinguishing these species.

below which individuals should be considered conspecific is unrealistic (even though many taxonomists have done so, in various contexts, for a great many years). Speciation is not tidy.

ACKNOWLEDGEMENTS

We thank Wally Medina for making distribution maps, Donald Harvey for dissecting genitalia, Young Sohn for drawing some of them, Karie Darrow for reducing and numbering the drawings, the ACG parataxonomists (see Burns & Janzen 2005a,

2005b, Miller *et al.* 2006) for finding and rearing caterpillars, Tanya Dapkey for plucking and shipping legs from reared adults for DNA analysis (i.e., "LEGS AWAY/FOR DNA"), Stephanie Kirk and Rebecca Cowling for molecular work, Janet Topan and Angela Holliss for DNA sequence analysis, and John Shuey and Felix Sperling for helpful comments. Support for this study came from the National Museum of Natural History Small Grants Program (J. M. B.); National Science Foundation grants BSR 9024770 and DEB 9306296, 9400829, 9705072, 0072730, and 0515699 (D. H. J.); and Genome Canada through the Ontario Genomics Institute, and the Gordon and Betty Moore Foundation (P. D. N. H.).

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## THE INFLUENCE OF HURRICANE AND TROPICAL STORM ACTIVITY ON RESIDENT BUTTERFLIES IN THE LOWER FLORIDA KEYS

MARK H. SALVATO<sup>1</sup> AND HOLLY L. SALVATO

1765 17th Avenue, Southwest, Vero Beach, Florida 32962, USA, email: anaea\_99@yahoo.com

**ABSTRACT.** Butterfly populations were monitored at two coastal locations in the lower Florida Keys to observe and evaluate their response to hurricane and tropical storm activity. Four major hurricanes—Dennis, Katrina, Rita and Wilma—occurred within the vicinity of the Florida Keys during 2005. The ocean-facing exterior portions of both study areas were heavily damaged by hurricane and tropical storm force winds, salt spray and storm surge, resulting in greatly reduced butterfly abundance and species richness. More interior portions of the study areas, while inundated with floodwaters, retained the majority of their vegetation throughout the storm season allowing for an assemblage of butterflies similar in richness, albeit reduced in abundance, to pre-storm conditions. At each study area butterfly recovery time appeared related to availability of appropriate host and nectar plant species. However, the decline, disappearance or slow recovery of certain butterflies suggests that storm activity had a deleterious influence on the natural histories of select butterflies.

**Additional key words:** adverse weather, population dynamics, *Cyclargus*.

Butterflies of the Florida Keys have adapted over time to the influence of tropical storms and other forms of adverse weather conditions (Covell 1976, Minno and Emmel 1993, Smith *et al.* 1994). However, aside from merely mentioning the threat that hurricanes may pose to localized populations of endangered species in the region (Minno and Emmel 1993, 1994, USFWS 1999, Calhoun *et al.* 2000), there is a scarcity of published data on the effects of tropical storms on butterfly populations and their natural histories. During the active storm season of 2005, we closely monitored butterflies at two locations in the lower Florida Keys to observe and evaluate their response to hurricane and tropical storm activity. Surveys of the study areas conducted by the authors during 2004, in which no substantial storm activity occurred in the lower keys, provided a baseline for comparison.

### METHODS

**The survey areas and pre-storm butterfly diversity.** Cactus Hammock, located on southeastern Big Pine Key within the National Key Deer Refuge (NKDR), contained a variety of plant communities, including coastal scrub, mangroves, salt marsh and tropical hardwood hammocks that allowed for a diversity of butterfly species. *Brephidium isophthalma pseudofea* (Morrison) (Lycaenidae) is prolific in coastal areas within the lower keys, including Cactus Hammock, where the species hostplants, *Salicornia bigelovii* L. (Chenopodiaceae) and *Batis maritima* L. (Bataceae) are abundant (Minno and Emmel 1993, Salvato 1998). Other species frequently encountered within Cactus Hammock historically included *Junonia*

*evarete* (Cramer) (Nymphalidae), *Strymon martialis* (Herrich-Schäffer) (Lycaenidae), *Ascia monuste phileta* Fabricius (Pieridae), *Heliconius charithonia tuckeri* Comstock and Brown (Nymphalidae), and *Panoquina panoquinoides* (Skinner) (Hesperiidae) (Salvato and Salvato, unpublished data). A 5-hectare portion of Cactus Hammock was monitored during this study to observe the possible influence of tropical storm conditions on butterfly species richness and abundance.

Bahia Honda State Park (Bahia Honda), located approximately 8 km (5 miles) east of Big Pine Key, also had a variety of natural habitats, including tropical hammocks, mangroves, coastal scrub and beaches, as well as an old berm that historically served as a railroad bridge. The areas surrounding this berm were heavily vegetated on both the south (Atlantic Ocean) and north (Gulf of Mexico) sides by a variety of native plant species. Our surveys at Bahia Honda were limited to an area approximately 1-hectare in size along the old railroad berm. Vegetation within the study site included *Coccoloba uvifera* L. (Polygonaceae), *Suriana maritima* L. (Surianaceae) and *Caesalpinia bonduc* Roxburgh (Fabaceae), the latter of which is a hostplant of the endangered *Cyclargus thomasi bethunebakeri* Comstock and Huntington (Lycaenidae) (Pyle 1981, Calhoun *et al.* 2000). Other butterfly species occurring on Bahia Honda prior to the survey period included *Phoebus agarithe maxima* (Neumoegen) (Pieridae), *Agraulis vanillae nigrior* Michener (Nymphalidae), *H. c. tuckeri*, *Hemiargus ceraunus antibubastus* Hübner (Lycaenidae), *Leptotes cassius theonus* (Lucas) (Lycaenidae), *Hylephila phyleus phyleus* (Drury) (Hesperiidae) and *Cymaenes tripunctus tripunctus* (Herrich-Schäffer) (Hesperiidae) (Minno and Emmel 1993, Smith *et al.* 1994, Calhoun *et al.* 2000, Salvato and Salvato, unpublished data).

<sup>1</sup>Biologist, United States Fish and Wildlife Service, Vero Beach, Florida 32960, USA

The study areas were monitored monthly from June 2005 to February 2006 to determine butterfly abundance and species richness. A standard walking route was established at each location that allowed two researchers to observe and record butterfly activity within the varied environs of each survey location. Both locations were visited on each survey date, except during November 2005, when Cactus Hammock and Bahia Honda were surveyed on 5 November and 11 November, respectively (Bahia Honda was closed to the public due to storm damages on 5 November). Surveys were conducted on warm, clear days under conditions that were considered sufficient for butterflies to be flying. Each sampling date included approximately 6–8 hours of field time (between 8:00–16:00 h). On each sampling date approximately 4 to 5 and 2 to 3 hours were spent monitoring at Cactus Hammock and Bahia Honda, respectively. Butterfly diversity was determined on each sampling date by visually observing and recording the individuals and species encountered. Both researchers traversed the same survey route in unison, with one researcher (MHS) counting (with a hand counter) the most numerous species flying on a given sampling date while HLS tallied the remaining less abundant species.

**The storms.** Four major hurricanes—Dennis, Katrina, Rita and Wilma—occurred within the vicinity of the Florida Keys during 2005 (Fig. 1 indicates the relative paths for each storm). Storm accounts discuss data gathered and summarized by the National Oceanic

and Atmospheric Administration (NOAA) for Key West, Florida ([www.nhc.noaa.gov/archive/2005](http://www.nhc.noaa.gov/archive/2005)), which was located 48.3–56.3 km (30–35 miles) to the southwest of the study areas on Big Pine and Bahia Honda Keys. Dennis, had been a strong Category 4 hurricane (winds in excess of 241 km [150 mph]) prior to landfall in south-central Cuba, but weakened as it entered the southern Gulf of Mexico. Dennis passed approximately 137 km (85 miles) to the west of Key West on 9 July 2005 generating hurricane and tropical storm force winds in the extreme lower keys and a storm surge of up to 1.8 m (6 feet) above normal high tide levels within our coastal survey areas. Katrina, which crossed southern peninsular Florida and entered the Gulf as a weak hurricane, passed 28 km (45 miles) to the northwest of Key West on 26 August 2005 generating tropical storm force winds and storm surge on the northern side of the keys. Katrina had little influence on our study areas on southern Big Pine and Bahia Honda Keys. Rita passed within 81 km (50 miles) of Key West on 20 September 2005 and rapidly intensified as it traversed the entire stretch of the Straits of Florida. Rita's relatively close proximity generated hurricane and tropical storm force winds of greater duration and intensity than Dennis, with a storm surge up to 2.1 m (7 feet) above normal high tide levels within our study area. Wilma, which passed rapidly to the northeast of the lower keys on 24 October 2005, generated hurricane and tropical storm force winds and a storm surge up to 2.7 m (9 feet) that resulted in extensive damages on the

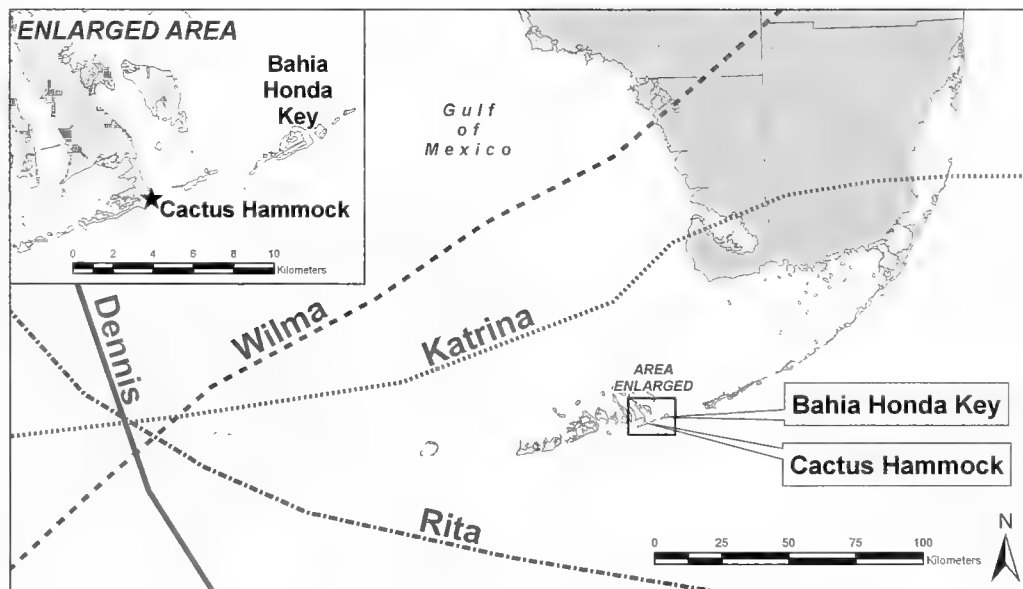


FIG. 1. The paths of Hurricane Dennis, Katrina, Rita and Wilma in relation to south Florida and the study areas in the lower keys.



FIG. 2. Exterior of Cactus Hammock, as shown on 24 September 2005, shortly after Rita, was severely damaged from hurricane and tropical storm force winds, salt spray and storm surge (Photo Credit; H.L. Salvato).

northern side of the lower keys. However, as with Katrina, this storm had little direct impact to our survey areas on the southern sides of the islands.

#### RESULTS

**Cactus Hammock-post storms.** A survey conducted on 16 July 2005, one week following Dennis, found that the majority of hammock and coastal scrub habitat along the coastal exterior of Cactus Hammock had been either severely damaged or destroyed by tropical storm force winds, salt spray and storm surge. Aside from migratory species such as, *A. m. phileta* and *P. a. maxima*, no other butterfly activity was observed within the heavily damaged exterior portions of Cactus Hammock. The interior of Cactus Hammock, while inundated with floodwaters, was otherwise undamaged. These more inland portions of the survey area maintained a richness of butterfly species similar to what was recorded prior to the storm; however, overall butterfly abundance was greatly reduced, particularly for Lycaenids, such as *B. i. pseudofea*, *L. c. theonus* and *H. c. antibubastus*. *Papilio cresphontes* Cramer (Papilionidae), *P. panoquinoides* and *H. c. tuckeri*, species frequently encountered within Cactus Hammock prior to Dennis, were absent following the storm. Additional post-Dennis surveys of Cactus Hammock indicated that several butterfly species, such as *J. evarete*, *A. m. phileta* and *Anartia jatrophae guantanamo* Munroe (Nymphalidae), had dispersed within the survey area and were observed ovipositing on available hostplants. However, butterfly abundance and species richness within Cactus Hammock continued to decline post-Dennis, while select species remained absent.



FIG. 3. Floodwaters intruded deep into Cactus Hammock following storm activity as a result of coastal dune erosion along the southeastern portion of the study area, covering extensive areas of *Salicornia* (Photo Credit; H.L. Salvato).

Rita passed directly to the south of the lower keys, generating storm surge, hurricane and tropical storm force winds, further adding to the damages initially caused by Dennis. Although quantitative measures on vegetation were not conducted as part of this study, we visually estimated that 60–80% of the hammock vegetation had been damaged or destroyed during Dennis and Rita (Fig. 2). Floodwaters that had receded during the interim between storms intruded deeper into Cactus Hammock following Rita as a result of coastal dune erosion along the southeastern portion of the study area (Fig. 3). Natural rehabilitation of coastal and hammock vegetation that had begun shortly after Dennis was hindered due to the influence of Rita. The abundance of select butterflies continued to decline,



FIG. 4. Storm surge and salt spray from Dennis and Rita greatly damaged vegetation on the ocean side of the Bahia Honda survey area, such as *Caesalpinia bonduc*, host plant for the endangered *Cyclargus thomasi bethunebakeri* (Photo Credit; H.L. Salvato).

while other species either decreased or remained absent. Overall butterfly richness within the area following Rita and into the fall of 2005 was much lower from what was noted during the previous year. Butterflies that were observed in Cactus Hammock during the late summer and fall months consisted largely of migratory species such as *Phoebus sennae eubule* (L.) (Pieridae), *Urbanus proteus proteus* (L.) (Hesperiidae) and *Danaus plexippus* (L.) (Nymphalidae), which were found nectaring on *Stachytarpheta jamaicensis* (L.) Vahl (Verbenaceae). *Danaus plexippus* was observed roosting on damaged and defoliated hammock trees along the coastal portions of the study site.

Wilma resulted in extensive damage on the Gulf side of the keys. However, a survey of Cactus Hammock on 5 November 2005, two weeks after Wilma, found little indication of major damage from this storm. New foliage that was sprouting on trees and shrubs that had been damaged or defoliated by Hurricanes Dennis and Rita appeared unaffected by Wilma. However, butterfly species richness and abundance continued to decline. In mid-December 2005 and into early 2006, with the exception of *B. i. pseudofoea*, which appeared to be returning to seasonal abundance, overall species

richness and abundance in Cactus Hammock remained lower from what had been recorded during the previous year and prior to the first storm activity of 2005.

Figures 5 and 6 indicate monthly butterfly species richness and abundance observed in Cactus Hammock from June 2005 to February 2006 during and following an active storm season. Also included is similar data on butterflies in the survey area collected during the same period of the prior year (June 2004 to February 2005), in which no substantial storm activity occurred within the lower keys. Appendix 1 indicates which species were encountered on each sampling date during the survey periods in 2004–2006 and their abundance.

**Bahia Honda-post storms.** On Bahia Honda, the ocean side of the old railroad berm was heavily damaged by storm surge and salt spray from Dennis (Fig. 4). One week after Dennis (16 July 2005), with the exception of migrating *A. m. phileta*, *P. a. maxima* and *Kricogonia lyside* (Godart) (Pieridae), no butterfly activity was observed on the ocean side of the survey area. We visually estimated that as much as 50% of the vegetation on the southern side of the island had been heavily damaged, including large stands of *C. bonduc*, *S. maritima* and other host and nectar plants of importance to butterflies on Bahia Honda. However,

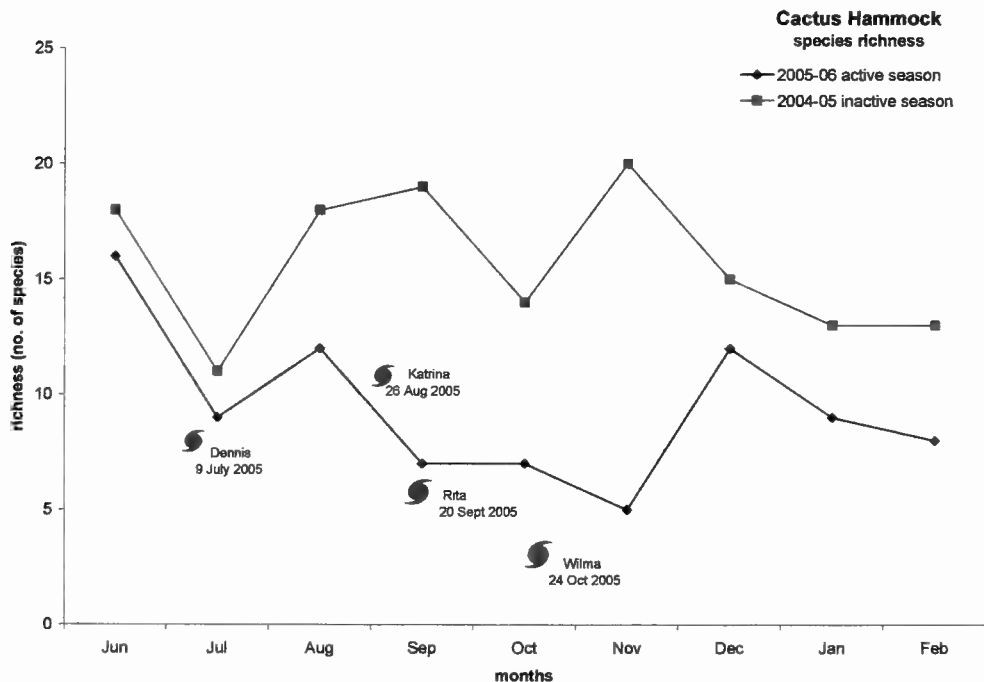


FIG. 5. Indicates monthly butterfly species richness observed in Cactus Hammock from June 2005 to February 2006 during and following an active storm season. Also indicated is similar data on butterflies in Cactus Hammock collected during the same period the prior year (June 2004 to February 2005), in which no substantial storm activity occurred in the lower keys.

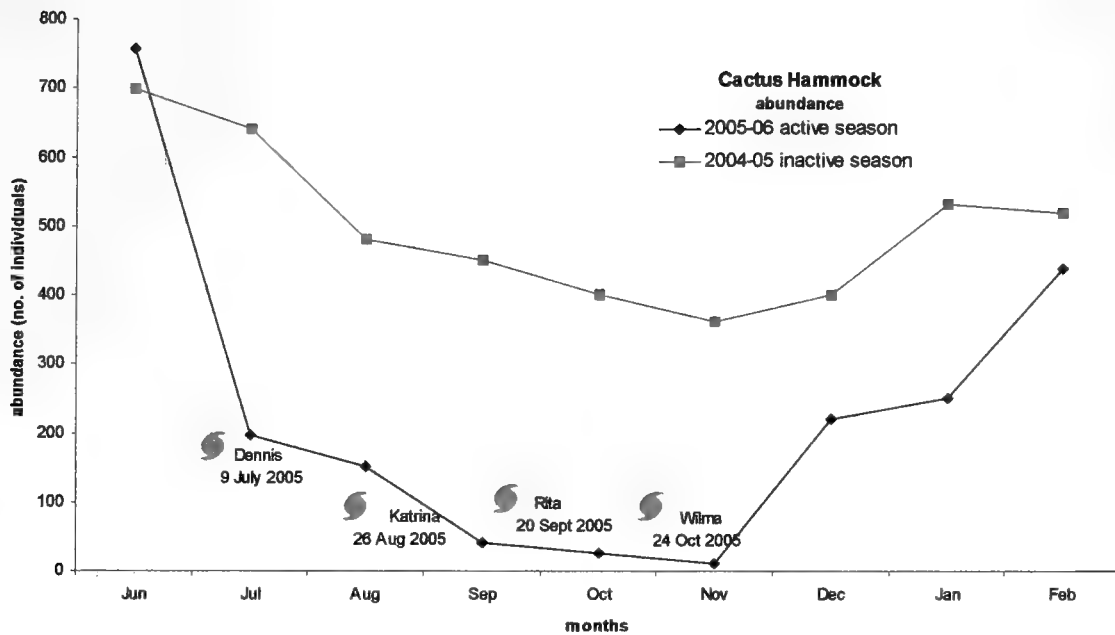


FIG. 6. Indicates monthly butterfly species abundance observed in Cactus Hammock from June 2005 to February 2006 during and following an active storm season. Also indicated is similar data on butterflies in Cactus Hammock collected during the same period the prior year (June 2004 to February 2005), in which no substantial storm activity occurred in the lower keys.

the remaining portions of the survey area, including the areas on top and to the northern side of the old railroad berm itself, appeared relatively undisturbed from storm surge and salt spray. Whereas butterfly activity was largely absent on the ocean side of the survey area, the Gulf side retained its vegetation and numerous plants remained in bloom. *Heliotropium angiospermum* Murray (Boraginaceae), *Bidens alba* L. (Asteraceae) and *Melanthera nivea* Small (Asteraceae), were heavily visited by surviving butterflies.

Unlike Cactus Hammock, where a decline in butterfly abundance was noted following Dennis, the level of butterfly activity increased on Bahia Honda from densities recorded prior to the storm. Similar to Cactus Hammock, however, was increased butterfly activity within areas less impacted from storm activities, which retained ample nectar sources and appropriate hostplants. The increased abundance in the select parts of this study area may have been the result of butterfly dispersal from storm-damaged areas of Bahia Honda and surrounding islands. As a result of natural regeneration and park maintenance, much of the vegetation was observed recovering during continued post-Dennis surveys. However, populations of several butterfly species, such as *C. t. bethunebakeri* and *H. c. tuckeri*, declined steadily. Although both of these

species lost large quantities of their respective hostplants on the ocean side of Bahia Honda as a result of Dennis, this reduction did not appear so substantial as to trigger such sharp declines.

As with Cactus Hammock, storm surge and salt spray from Rita greatly damaged vegetation on the ocean side of the old railroad berm. The impacts to the ocean side of the island appeared more severe, perhaps due to the fact that large amounts of coastal vegetation had been damaged or thinned by Dennis. This vegetation may have served as a protective barrier for the study area during the first storm. Overall species richness and abundance in late September and into November decreased following Rita and was reduced from levels observed during the previous year or earlier in the 2005 survey period.

Wilma caused extensive damage to the northeastern side of Bahia Honda; however, we observed little storm impact on our study area on the southwestern portion of the island during a survey on 11 November 2005, about three weeks after the storm. Surveys of Bahia Honda in mid-December 2005 and into early 2006 found butterfly richness and abundance similar to that observed a year prior and earlier in the survey period, indicating that butterflies were returning to relatively normal seasonal densities.

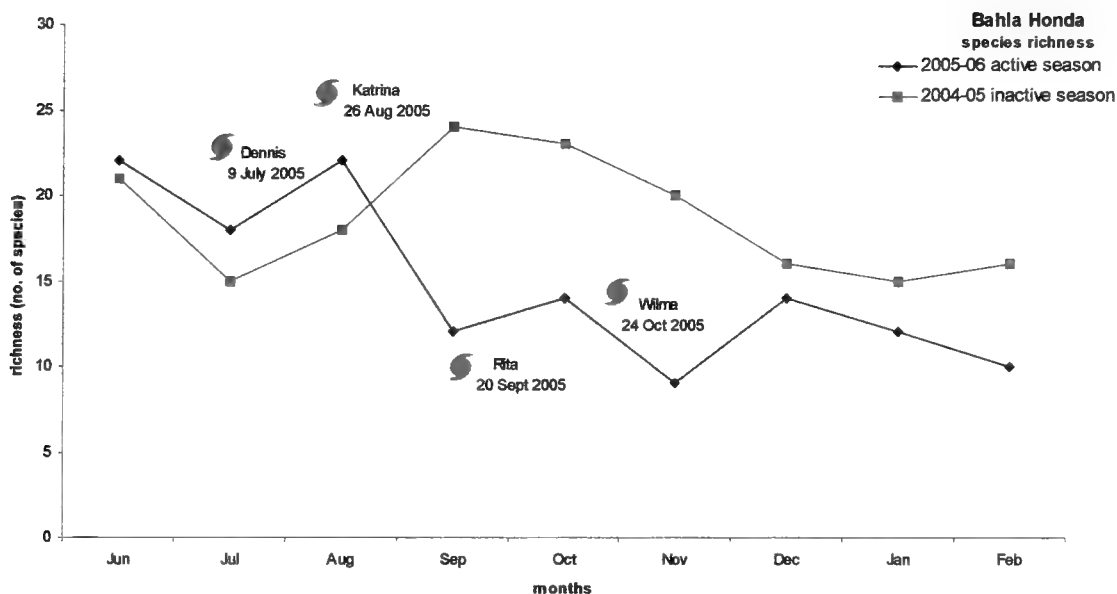


FIG. 7. Indicates monthly butterfly species richness observed on Bahia Honda from June 2005 to February 2006 during and following an active storm season. Also indicated is similar data on butterflies on Bahia Honda collected during the same period the prior year (June 2004 to February 2005), in which no substantial storm activity occurred in the lower keys.

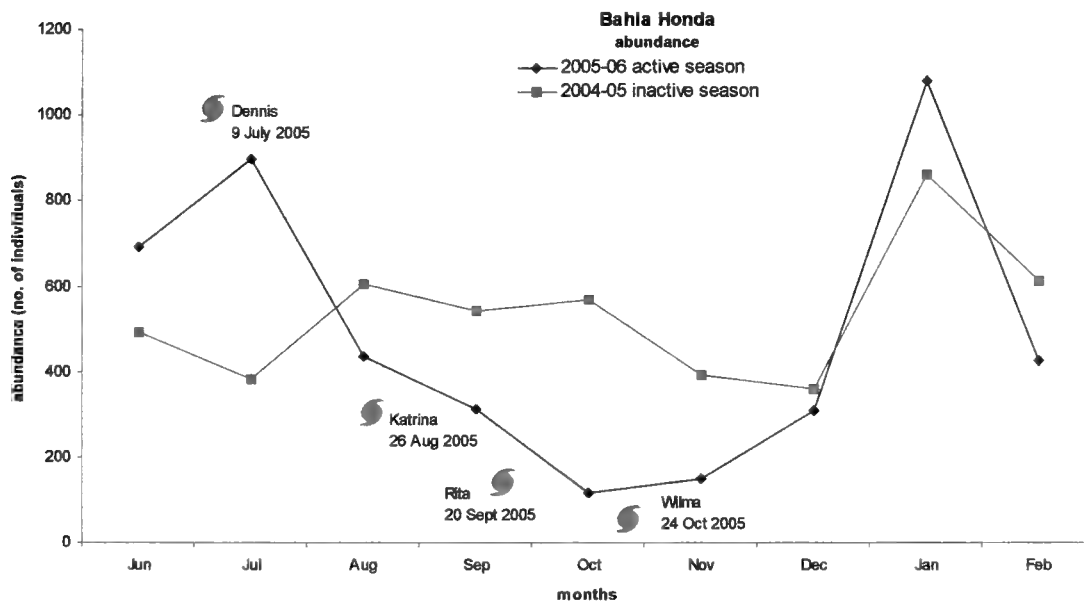


FIG. 8. Indicates monthly butterfly species abundance observed on Bahia Honda from June 2005 to February 2006 during and following an active storm season. Also indicated is similar data on butterflies on Bahia Honda collected during the same period the prior year (June 2004 to February 2005), in which no substantial storm activity occurred in the lower keys.

Figures 7 and 8 indicate monthly butterfly species richness and abundance observed in Bahia Honda from June 2005 to February 2006 during and following an active storm season. Also included is similar data on butterflies in the survey area collected during the same period of the prior year (June 2004 to February 2005), in which no substantial storm activity occurred within in the lower keys. Appendix 2 indicates the species that were encountered on each sampling date during the survey periods in 2004–2006 and their abundance.

#### DISCUSSION

Butterflies that readily re-established themselves within the survey areas after the storms were those species most closely associated with salt marsh, mangrove and hammock vegetation that had rebounded rapidly after Dennis and Rita. In Cactus Hammock, *A. m. phileta*, *P. a. maxima*, *B. i. pseudofea*, *Strymon istapa modestus* Maynard (Lycaenidae), *J. evarete*, *A. j. guantanamo*, *Phoicides pigmalion okeechobee* (Worthington) (Hesperiidae) and *Polygonus leo savigny* (Latreille) (Hesperiidae) (all dependant on plant species that quickly returned after the storms) were species that were most often re-encountered following the storms. The decline, disappearance or slow recovery of select species within the remainder of Cactus Hammock (such as *H. c. tuckeri*), suggests that storm activity had a deleterious influence on the natural histories of select butterflies. Species that had occurred locally within Cactus Hammock prior to the storms (such as *S. martialis* and *P. panoquinoides*), but not after them, will require ongoing monitoring to determine their status.

Although recovery was rapid for many of the butterfly species within the Bahia Honda survey area following the storms, a number of species remained in decline or absent in post-storm surveys. *Heliconius c. tuckeri* was abundant immediately after the initial storm, but was not recorded again in the Bahia Honda survey area for the remainder of the study. *Leptotes c. theonus* and *S. martialis* disappeared from Cactus Hammock shortly

after Dennis, but both quickly re-established themselves on Bahia Honda and elsewhere in the lower keys. This suggests that they may rely on a more storm-impacted host plant within Cactus Hammock, resulting in the differing recovery outcomes. Despite the noted decline of the endangered *C. t. bethunebakeri* throughout the survey period further monitoring by the authors found that the species had returned to pre-storm abundance by the summer months of 2007.

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Please see the next 4 pages for Appendices.

Continued



APPENDIX 1. The butterfly species encountered in Cactus Hammock during each sampling date during the survey periods in 2004-2006 and their abundance.

Species	2004							2005	
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
<i>Papilio cresphontes</i>	4	0	1	0	1	1	0	0	0
<i>Ascia m. phileta</i>	225	195	36	12	0	6	8	14	10
<i>Phoebus s. eubale</i>	0	0	0	12	2	3	0	0	0
<i>P. a. maxima</i>	22	12	17	13	1	2	0	0	2
<i>Kricogonia lyside</i>	0	0	0	0	0	0	0	0	0
<i>Leptotes c. theonus</i>	87	55	37	23	27	20	25	23	20
<i>Hemiargus c. antibubastus</i>	42	25	22	23	13	15	12	10	6
<i>Brephidium i. pseudofea</i>	245	325	317	313	280	225	267	395	451
<i>Strymon i. modestus</i>	2	0	3	1	0	0	6	4	0
<i>S. martialis</i>	4	0	2	1	0	2	4	3	1
<i>Agraulis v. nigror</i>	12	15	12	15	25	23	18	25	12
<i>Heliconius c. tuckeri</i>	10	5	12	9	6	14	5	12	14
<i>Junonia genoveva</i>	2	0	1	1	3	2	2	0	0
<i>J. evarete</i>	12	1	2	12	25	22	12	14	3
<i>J. coenia</i>	0	0	0	0	0	0	0	0	0
<i>Anartia j. guantanamo</i>	4	1	2	2	0	2	22	8	2
<i>Danaus plexippus</i>	0	0	0	0	0	12	0	0	0
<i>D. gilippus</i>	0	0	0	0	0	0	0	0	0
<i>Phycoides phaon</i>	0	0	0	0	0	0	0	0	0
<i>Urbanus p. proteus</i>	0	0	0	1	1	2	0	0	0
<i>Phocides p. okeechobee</i>	6	0	2	2	0	2	5	6	3
<i>Polygonus l. savigny</i>	2	0	1	2	2	2	2	8	4
<i>Pyrgus o. oileus</i>	4	0	3	2	1	2	0	0	0
<i>Hylephila p. phyleus</i>	0	0	0	0	0	0	0	0	0
<i>Wallengrenia otho</i>	13	2	8	4	12	3	12	10	2
<i>Panoquina panoquinoides</i>	3	5	2	1	0	1	1	0	0



APPENDIX 2. The butterfly species encountered on Bahia Honda Key during each sampling date during the survey periods in 2004-2006 and their abundance.

Species	2004							2005	
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
<i>Papilio cresphontes</i>	2	1	0	0	0	0	0	0	0
<i>Ascia m. phileta</i>	197	212	25	15	26	14	5	6	2
<i>Phoebus s. eubale</i>	0	0	12	12	15	3	0	0	0
<i>P. a. maxima</i>	21	13	4	6	10	8	6	2	4
<i>P. p. philea</i>	1	0	2	1	2	0	0	0	0
<i>Nathalis iole</i>	0	15	0	2	5	0	0	0	0
<i>Eurema l. lisa</i>	0	0	0	5	5	0	2	1	0
<i>E. daira</i>	0	0	0	1	3	0	0	0	0
<i>Kricogonia lyside</i>	0	12	5	12	2	2	0	0	0
<i>Leptotes c. theonus</i>	34	27	45	41	25	37	35	142	174
<i>Hemiargus c. antibubastus</i>	18	20	25	15	10	12	18	15	23
<i>Cyclargus t. bethunebakeri</i>	28	35	15	55	75	46	27	53	69
<i>Electrostrymon a. angelia</i>	2	1	0	1	0	0	0	0	0
<i>Strymon i. modestus</i>	7	3	10	12	12	16	12	7	15
<i>S. martialis</i>	6	3	1	1	10	23	13	15	12
<i>Agraulis v. nigrior</i>	73	35	255	202	175	82	95	275	200
<i>Heliconius c. tuckeri</i>	85	5	150	97	105	61	75	110	65
<i>Dryas i. largo</i>	0	0	0	0	0	0	0	0	0
<i>Anartia j. guantanamo</i>	2	0	10	12	12	13	25	209	24
<i>Vanessa cardui</i>	1	0	0	0	0	0	0	0	0
<i>Junonia evarete</i>	0	0	0	0	0	0	0	0	0
<i>J. coenia</i>	0	0	0	0	0	0	0	0	0
<i>Danaus plexippus</i>	0	0	0	0	0	22	0	0	0
<i>D. gilippus</i>	0	0	0	2	8	8	0	0	0
<i>Urbanus p. proteus</i>	0	0	0	1	0	2	4	2	2
<i>Phocides p. okeechobee</i>	2	0	15	13	15	3	2	2	0
<i>Polygonus l. savigny</i>	1	0	0	2	6	7	4	0	2
<i>Pyrgus o. oileus</i>	1	0	1	0	0	0	0	0	2
<i>Hylephila p. phyleus</i>	4	1	10	15	20	16	20	14	15
<i>Polites v. vibex</i>	2	1	10	8	6	6	0	0	2
<i>Wallengrenia otho</i>	3	0	10	12	20	12	15	8	2
<i>Cymaenes t. tripunctus</i>	1	0	0	0	1	0	0	0	0

## APPENDIX 2. Continued.

Species	2005							2006	
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
<i>Papilio cresphontes</i>	0	2	1	0	0	0	0	0	0
<i>Ascia m. phileta</i>	125	116	87	15	5	0	1	0	0
<i>Phoebus s. eubale</i>	0	0	0	12	6	1	0	0	0
<i>P. a. maxima</i>	25	47	32	14	1	0	1	1	2
<i>P. p. philea</i>	2	0	2	0	0	0	0	0	0
<i>Nathalis iole</i>	0	0	0	0	0	0	0	0	0
<i>Eurema l. lisa</i>	2	0	1	1	2	0	1	0	0
<i>E. दौरा</i>	2	0	1	0	0	0	0	1	0
<i>Kricogonia lyside</i>	28	32	27	7	0	0	0	0	0
<i>Leptotes c. theonus</i>	27	26	29	24	5	25	155	325	152
<i>Hemiargus c. antibubastus</i>	39	38	35	28	23	10	32	10	12
<i>Cyclargus t. bethunebakeri</i>	57	82	30	10	6	17	2	1	0
<i>Electrostrymon a. angelia</i>	6	2	1	0	0	0	0	0	0
<i>Strymon i. modestus</i>	16	62	20	4	1	0	3	2	42
<i>S. martialis</i>	6	12	4	0	1	28	2	5	12
<i>Agraulis v. nigrior</i>	224	268	132	187	60	35	88	371	190
<i>Heliconius c. tuckeri</i>	114	197	18	0	0	0	0	0	0
<i>Dryas i. largo</i>	0	0	0	0	1	0	0	3	0
<i>Anartia j. guantanamo</i>	2	0	5	8	0	1	12	354	5
<i>Vanessa cardui</i>	0	0	2	0	0	0	0	0	0
<i>Junonia evarete</i>	1	0	0	0	0	0	0	0	0
<i>J. coenia</i>	0	0	0	0	2	0	0	0	0
<i>Danaus plexippus</i>	0	0	0	0	0	30	0	0	1
<i>D. gilippus</i>	0	0	0	0	0	0	0	0	0
<i>Urbanus p. proteus</i>	0	1	0	0	0	2	2	0	2
<i>Phocides p. okeechobee</i>	0	0	0	0	0	0	3	0	0
<i>Polygonus l. savigny</i>	1	1	0	0	0	0	0	0	0
<i>Pyrgus o. oileus</i>	1	0	1	0	0	0	0	0	0
<i>Hylephila p. phyleus</i>	7	5	5	2	2	0	4	6	8
<i>Polites v. vibex</i>	2	1	1	0	0	0	0	0	0
<i>Wallengrenia otho</i>	3	3	2	0	1	0	2	1	0
<i>Cymaenes t. tripunctus</i>	3	3	1	0	0	0	0	0	0

FIRST REPORT OF *OECOPHORA BRACTELLA* (L.) (OECOPHORIDAE) IN NORTH AMERICA

MERRILL A. PETERSON

(MAP) Biology Department, Western Washington University, Bellingham, WA 98225, USA (e-mail: peterson@biol.wvu.edu)

ERIC H. LAGASA

(EHL) Washington State Department of Agriculture, Olympia, WA 98504, USA (e-mail: elagasa@agr.wa.gov)

STEVEN PASSOA

(SP) USDA, APHIS, PPQ, The Ohio State University, Museum of Biodiversity, 1315 Kinnear Rd., Columbus, OH 43212, USA  
(e-mail: Steven.C.Passo@usda.gov)

GADEN S. ROBINSON

(GSR) Department of Entomology, Natural History Museum, Cromwell Road, London SW7 5BD, UK (e-mail: G.Robinson@nhm.ac.uk)

AND

DAVID HOLDEN

(DH) Canadian Food Inspection Agency, 400 - 4321 Still Creek Drive, Burnaby, BC V5C 6S7 Canada (e-mail: holdend@inspection.gc.ca)

**ABSTRACT.** The first report of *Oecophora bractella* (L.) from North America is given, based on collection records from Washington and British Columbia. This species is found throughout Europe, but is generally rare to uncommon through most of its range. Larvae occur on rotting wood in association with certain fungi and are not expected to reach pest status. Adults were captured at nine locations, with the first record from Seattle, WA in 1998. This first record and some of the subsequent records are from sites immediately adjacent to or associated with international shipping routes. Other sites with *O. bractella* are from residential areas, two of which have established breeding populations. The introduction of this moth is surprising, particularly given the low interception rate at United States ports and its specialized feeding niche. A diagnosis and photographs of adults are provided to enable North American researchers to identify this species and to monitor its spread.

**Additional key words:** Lepidoptera, Red Data Book, specialist, exotic, introduced, Pacific Northwest

We report in this paper the surprising discovery of *Oecophora bractella* (Linnaeus, 1758) in Washington and British Columbia, apparently reflecting an introduction of this species to North America from Europe. *Oecophora bractella* is widely known in Europe, including the UK, as a strikingly beautiful, but infrequently seen, microlepidopteran occurring from the British Isles (but not Ireland) and the southern half of Scandinavia south to the Mediterranean and east to western Estonia and the Ukraine (Karsholt & Razowski 1996; Jürivete *et al.* 2000; Lvovsky 2003). *Oecophora bractella* has a provisional listing as rare ('pRDB3') in the UK's Red Data Book (Kimber 2007), has similar Red Data Book status in both Estonia (Commission for Nature Conservation of the Estonian Academy of Sciences, 2002) and the Austrian state of Carinthia (Wieser & Hümer 1999), and is considered 'regionally threatened' in continental Finland (K. Silvonen, pers. comm.). In many other parts of its range, *O. bractella* does not have a formal conservation listing, but it is generally characterized as being scarce or having a localized distribution (Lindsey 2006; de Prins &

Steeman 2007). The exceptions to this general pattern are Sweden, where *O. bractella* is considered locally common (N. Ryrholm pers. comm.), and eastern Denmark, where it is generally common (Palm 1989).

The larvae of *O. bractella* feed in the bark of decaying wood, often in close association with the mycelia of fungi, especially honey fungus (*Armillaria mellea* (Vahl:Fr.) Kummer) (Sterling, 1984). It remains unclear whether the larvae eat these fungi (Harper *et al.* 2002). Larvae can be found in the bark of a variety of different tree species, including *Quercus*, *Betula*, *Fraxinus*, *Corylus*, *Prunus*, *Larix*, *Pinus*, *Picea*, and *Tsuga*, feeding from January to May in the UK. Larvae typically live under a loose layer of silk and frass (Harper *et al.* 2002). Between April and June, they pupate in their feeding sites, forming a cocoon also lined with silk and frass. Adults fly from late May to the end of July in the UK, where *O. bractella* is considered to be univoltine (Harper *et al.* 2002). In Denmark, the flight season is slightly longer (mid-May to mid-August), suggesting possible bivoltinism (Palm 1989). Adults are primarily crepuscular, being most active from the early morning

light to sunrise, as well as in the late afternoon and evening (Harper *et al.* 2002; Palm 1989). They are seldom found at lights (Kimber 2007) and spend most of the daylight hours in seclusion (de Prins & Steeman 2007).

The reliance of *O. bractella* on dead wood, coupled with its apparent association with specific fungi, may explain why this species is generally limited to ancient woodlands in the UK (Harper *et al.* 2002; Kimber 2007). Its scarcity in the UK may also be exacerbated by the common forestry practice of removing trees that are infected with *Armillaria mellea*, a policy motivated by the fact that the fungus can kill stressed

trees (Sterling 1984).

The specialized life history (Sakai *et al.* 2001; Suarez *et al.* 2005), and scarcity of interception records for this species at U.S. ports (USDA, APHIS, PPQ Pest Interception Database (PestID), Riverdale, Maryland) suggests that *O. bractella* should be an unlikely species for inadvertent introduction. Nonetheless, we report herein its establishment in western North America. In addition, we describe the species and provide photographs of living and pinned specimens, both to facilitate recognition of this species, and to enable North American entomologists to monitor its spread. The introduction of this species

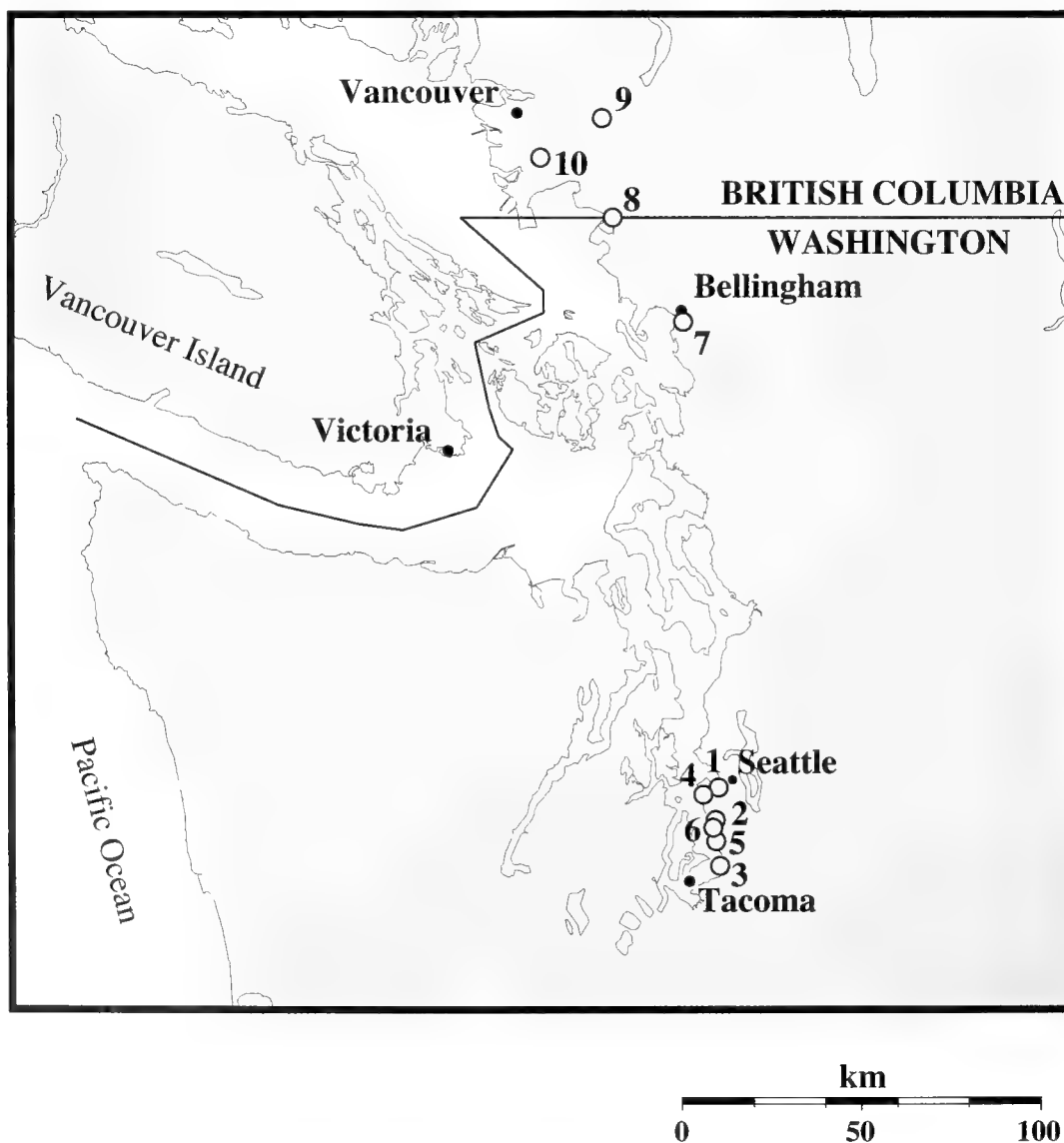


FIG. 1. Distribution of collection records for *O. bractella* in Washington and British Columbia. Open circles and site numbers correspond to the sites listed in Table 1. Closed circles indicate the location of cities. This map was generated with Online Map Creator ([http://www.aquarius.geomar.de/make\\_map.html](http://www.aquarius.geomar.de/make_map.html)).

adds to a growing list of wood-associated oecophorids of European origin that have been introduced to this continent (Powell 1964, 1968; Hodges 1974).

***Oecophora bractella* in North America.** The first specimen of *O. bractella* found in North America was a male taken at a blacklight trap in the industrial area of Seattle, Washington on June 30, 1998. Two and a half weeks later, a second male was taken in this same trap. Subsequent to this collection, an additional eight specimens were collected in pheromone traps at five other south Seattle locations, most of which were in residential areas (Table 1). Interestingly, these moths were found in traps baited with four different pheromones. The pheromone-trap and light-trapping surveys in which these specimens were captured were annual projects funded in part by grants from USDA APHIS, as part of the national Cooperative Agricultural Pest Survey (CAPS) program. In addition to the Seattle-area specimens, numerous *O. bractella* specimens have been collected more recently at three locations N of Seattle, near the US/Canada border (Table 1). Four of these specimens were found in a residential neighborhood in Bellingham, one was found on a pallet upon inspection for U.S. import in Blaine, Washington, and the rest were captured in a residential neighborhood in Port Coquitlam, British Columbia and a riparian area in Burnaby, British Columbia. The locations of all known North American collection sites for *O. bractella*, indicated in Fig. 1, are listed in Table 1, with collection and deposition data. A USDA, APHIS, PPQ Pest Interception Database query turned up no reports of interceptions of *O. bractella* at ports and airports other than the Blaine, WA specimen.

The initial identification of *O. bractella* was made by one of the authors (GSR) on the basis of a photograph of a live specimen from Bellingham, WA (Fig. 2). This identification was confirmed by another author (SP) upon comparison of two Seattle-area males with both a specimen of German origin and literature illustrations of the genitalia (Palm 1978).

Several lines of evidence suggest that *O. bractella* was inadvertently introduced to North America via shipments of bulk wood products. First, because the larvae feed on *Armillaria*-infected dead tree trunks, the shipment of raw timber and/or bulk wood products could easily facilitate introduction of this species. More importantly, several of the collection locations are near international shipping terminals. Indeed, the first specimens recorded from the region were from near Seattle's shipping terminal, and the specimen from Blaine, WA was found in a shipping container upon inspection for U.S. import. The

container held wood pallets loaded with insulating bricks that were shipped from Denmark (Interception # APSWA061931374003, USDA, APHIS, PPQ Pest Interception Database (PestID), Riverdale, Maryland).

The establishment of breeding populations of *O. bractella* in North America has been confirmed at two locations (Bellingham, Washington, and Burnaby, British Columbia), where immatures were found in spring 2007. At Burnaby, a half dozen unknown larvae living under the peeling bark of a dying *Alnus rubra* were collected for rearing in March. On May 3 an adult male *O. bractella* was found in the rearing chamber. Subsequent collections in this riparian habitat yielded specimens on many different *A. rubra* offering similar larval habitats, as well as one ornamental *Acer* sp. in a nearby landscaped environment. Most collections were on dying standing trees, but some were on recently felled



FIG. 2. Live *O. bractella* female from Bellingham, Washington. Photograph by MAP.



FIG. 3. *O. bractella* female from Port Coquitlam, British Columbia. Photograph by DH.



trees. In this same vicinity, larvae were not found under peeling bark on completely dead trees with very little moisture content.

In Bellingham, larvae and pupae were found in a residential area on 29 May 2007 under the bark of 2"-4" diameter dead standing branches of *Laburnum anagyroides* Medik. (Fabaceae), an introduced ornamental commonly called Golden Chain Tree. Adults were subsequently reared from three of these larvae, and a fourth larva produced an unidentified tachinid. Also on 29 May 2007, adults were found on the bark of the dead branches as well as on nearby overhanging live branches of *L. anagyroides* and neighboring trees and bushes. From 29 May to 12 June 2007, 14–18 adults were associated with this *L. anagyroides* tree, with diminishing numbers thereafter until 17 July 2007. Larvae were present through the entire six week period.

Although breeding has not been documented at other sites from which adults have been collected, it is likely that this species is established outside of Burnaby and Bellingham. Notably, adults were found in two successive years at one site south of Seattle (Site 2).

It remains unclear whether the Pacific Northwest populations of *O. bractella* are associated with *Armillaria mellea*, the fungus with which larvae are typically associated in Europe. The larvae found in Bellingham were on branches that had peeling bark under which the wood was blackened, perhaps from fungal infection. At Burnaby, the highest densities of larvae appeared to be associated with an unknown bracket fungus but fungal feeding was not evident. Larvae under bark did not appear to be in close association with visible fruiting bodies or mycelia and they appeared to be rasping or chewing the surface of the phloem which resulted in a colour change of the sapwood. This discoloration was a good indicator of larval presence as was their frass filled silk webbing. Although some authors suggest that *Armillaria mellea* occurs in the Pacific Northwest (Shaw 1973), the taxonomy of this group has been recently revised (Burdall & Volk 1993). Under this revision, *A. mellea* is no longer considered to occur in Washington and Oregon, but other species of *Armillaria* are common in the region (Burdall & Volk 1993), suggesting that the fungal associations of this species may include more than one *Armillaria* species. Indeed, given the recent taxonomic changes for *Armillaria* (Burdall & Volk 1993), it is possible that some of the previously reported associations with *A. mellea* may be inaccurate. The fact that *A. mellea* is found in northern California and eastern North America

(Burdall & Volk 1993) suggests that *O. bractella* could become widespread in North America.

#### Formal nomenclature.

*Oecophora bractella* (Linnaeus, 1758)

*Phalaena* (*Tinea*) *bractella* Linnaeus, 1758, *Systema Naturae* (edn 10): 540, no. 280. Lectotype, ♀, ['Europa'] labelled '*bractella*' [by Linnaeus]/'*bractella* 894' [by J.E. Smith] designated by Robinson & Nielsen (1983: 204) (Linnaean collection, London).

*Phalaena bractella*; Clerck, 1759; *Icones Insectorum Rariorum*, pl. 12, fig. 4.

*Phalaena* (*Tinea*) †*bracteella*; Linnaeus, 1761, *Fauna Svecica* (edn 2): 366, no. 1426 [incorrect subsequent spelling].

*Oecophora bractella* (L.); Meyrick, 1922, *Genera Insectorum* 180: 21.

It is likely that Clerck figured Linnaeus's specimen, as there are no specimens in the Clerck collection (Robinson & Nielsen, 1983). High-resolution digital images of the lectotype should be available shortly through the Linnean typification project on the Linnean Society's website: <http://www.linnean.org>.

During the latter part of the nineteenth and the early twentieth century *bractella* was placed in the genus *Alabonia*, which was synonymized with *Oecophora* by Meyrick (1922).

**Diagnosis.** The adults and immature stages are described in detail elsewhere in the literature (e.g. Meyrick 1922; Toll 1964; Fetz 1994; Harper *et al.* 2002; Patočka & M. Turčáni 2005). Here, we discuss the diagnostic features of *O. bractella* adults (see also Figs. 2, 3) to allow identification by North American researchers. *Head and thorax:* The head and thorax are covered with bright yellow, appressed scales. The long, recurved labial palps are mostly dark fuscous, with pale tips and some yellow on the inner and ventral surfaces. The legs are dark fuscous with white tarsal and tibial rings. *Wings:* The forewings (5.5–7.5mm wing length) of *O. bractella* are dark brown or gray to black, patterned with bright yellow and metallic blue or purple patches. The basal 1/3 of the forewings is bright yellow, except along the costal margin, which is dark brown to black. Just distal to the basal yellow area is a band of metallic blue or purple scales, running straight from the costa to the dorsum, and separated from the yellow basal area by a thin band of dark fuscous to black. The forewing also features a single smaller anteapical yellow spot along the costal margin. Basal and medial to this spot is a short band of metallic blue or purple scales that does not reach the margin of either wing. The distal margin of the forewing features metallic blue or purple scaling. The fringe scales are generally dark fuscous to black, with those near the apex tipped with white. The

TABLE 1. Collection and deposition data for all known *Oecophora bractella* specimens from North America.

Locality	Date	Method	Collector	Determination	Number & Deposition <sup>1</sup>
<i>USA: Washington</i>					
1) King Co., Seattle, 47.57°N 122.34°W; industrial/port	30 June 1998	Blacklight	M. Allen	E.H. LaGasa	1 male; WSDA
	17 July 1998	Blacklight	M. Allen	S. Passoa	1 male; USNM
2) King Co., 4.8km N of Burien, 47.488°N 122.351°W; residential	8 August 2000	European Corn Borer lure trap <sup>2</sup>	P. Hertzog	S. Passoa	1 male; USDA
	2 July 2001	<i>Proeulia</i> lure trap <sup>2</sup>	P. Hertzog	E.H. LaGasa	1 sex unknown (missing abdomen & hindwings); WSDA
3) King Co., Saltwater State Park, Des Moines, 47.375°N 122.322°W; park/residential	2 August 2001	<i>Proeulia</i> lure trap <sup>2</sup>	P. Hertzog	E.H. LaGasa	2 males; WSDA (only one specimen retained) 1 female; WSDA
	7 August 2001	<i>Proeulia</i> lure trap <sup>2</sup>	P. Hertzog	E.H. LaGasa	
4) King Co., West Seattle, 47.552°N 122.398°W; residential	8 July 2002	Leek moth lure trap <sup>2</sup>	S. Williams	E.H. LaGasa	1 male; specimen not kept
5) King Co., Normandy Park, 47.433°N 122.348°W; residential	17 July 2002	Plum fruit moth lure trap <sup>2</sup>	S. Williams	E.H. LaGasa	1 male; specimen not kept
6) King Co., Burien, 47.467°N, 122.361°W; urban	17 July 2002	Plum fruit moth lure trap <sup>2</sup>	S. Williams	E.H. LaGasa	1 male; specimen not kept
7) Whatcom Co., Bellingham, 48.741°N 122.474°W; residential	17 June 2006	At window of house	M. Peterson	G. Robinson	1 female; WWU
	29 May 2007	Dead branches of <i>Laburnum anagyroides</i>	M. Peterson	M. Peterson	2 females, 1 male; WWU
8) Whatcom Co., Blaine, 49.000°N 122.738°W; import inspection station	11 July 2006	Shipping container	J. Boyer	S. Passoa	1 female; USDA
<i>CANADA: British Columbia</i>					
9) Port Coquitlam, 49.244° N 122.778°W; residential	23 June 2006	Mercury vapor lamp	D. Holden	G. Pohl	1 female; DH
	26 June 2006	Mercury vapor lamp	D. Holden	G. Pohl	2 females; CNC
	1 June 2007	Mercury vapor lamp	D. Holden	D. Holden	1 female; DH
	2 June 2007	Mercury vapor lamp	D. Holden	D. Holden	2 females; DH
	27 June 2007	Mercury vapor lamp	D. Holden	D. Holden	1 female; DH
	28 June 2007	Mercury vapor lamp	D. Holden	D. Holden	2 females; DH
	2 July 2007	Mercury vapor lamp	D. Holden	D. Holden	1 female; DH
	4 July 2007	Mercury vapor lamp	D. Holden	D. Holden	1 male; DH
10) Burnaby, 49.15° N 123.00°W; riparian near commercial development	30 May 2007	Sweep net	D. Holden	D. Holden	1 male; DH
	3 May 2007 to 12 June 2007	Reared from bark of <i>Alnus rubra</i> & <i>Acer</i> sp.	D. Holden	D. Holden	22 males; 20 females; DH

<sup>1</sup> WSDA = Washington State Department of Agriculture, Olympia, WA; USDA = U.S. Dept. of Agriculture, APHIS-PPQ, The Ohio State University, Museum of Biodiversity, Columbus, OH; USNM = Smithsonian Institution; WWU = Biology Department, Western Washington University, Bellingham, WA; DH = David Holden, personal collection; CNC = Canadian National Collection, Ottawa, ON.

<sup>2</sup> Pheromone lure traps consisted of gray rubber septa (West Co., Lionville, PA, cat. no. 1060-0275) loaded with specific pheromone lures, in a Pherocon 2 type trap. European Corn Borer lure: 0.5mg Z-11-14:AC, 0.5mg E-11-14:AC; *Proeulia* lure: 0.1mg E-11-14:OH; Leek Moth lure: 1 mg Z-11-16:AL; Plum Fruit Moth lure: 0.1mg Z-8-12:AC, 0.004mg E-8-12:AC, 0.025mg Z-8-14:AC, 0.005mg Z-10-14:AC, 0.2mg 14:AC.

hindwing is uniformly dark gray. *Rectiostoma fernaldella* (Riley, 1889) is the only gelechioid in western North America that could perhaps be confused with *O. bractella*. This species, occurring only in the SW U.S., is superficially similar to *O. bractella*, but the basal area of the forewing of *R. fernaldella* is dull (not bright) yellow, the forewing lacks an antepical yellow spot, the apex of the forewing is strongly squared off (not rounded), and the hindwings are broader than in *O. bractella*. The somewhat dorsoventrally-flattened larvae of *O. bractella* are grayish brown, with darker gray thoracic segments and terminal abdominal segment, and a brown head capsule. Each abdominal segment has a subdorsal furrow.

**Pest Status.** *O. bractella* is unlikely to attain pest status in North America, as its larvae feed in the bark of decaying wood. Although *O. bractella* is unlikely to have any economic effects, it is possible that its establishment could have minor ecological ramifications, through its impact on detritivore food webs. Perhaps of broader interest is that fact that the arrival of *O. bractella* underscores the ease with which species can exploit the colonization opportunities afforded by international shipping. Given the profound economic and environmental costs associated with invasive species that do attain pest status (Wilcove *et al.* 1998; Mack *et al.* 2000; Pimentel *et al.* 2001), the introduction of this rather uncommon and specialized species is alarming. Furthermore, this introduction underscores the difficulty in making generalities regarding which insects are most likely to be introduced (Simberloff 1989).

**Relevance to Conservation Efforts.** The residential and urban locales in Washington and British Columbia from which *O. bractella* has been recorded are unlike the habitats this species exploits in its native range. Through most of its range, *O. bractella* is generally restricted to forests and other wooded regions (Novák & Severa 1980; Palm 1989), while in the UK, it is generally restricted to ancient forests (Harper *et al.* 2002; Kimber 2007), and in Estonia, it is found only in sparse juniper woodlands on limestone with sparse vegetation (M. Martin, pers. comm.). However, in some regions this species is found in managed habitats such as hedgerows (Lindsey 2006). The ability of *O. bractella* to occupy residential habitats in North America suggests that further research on this species in North America may provide insights into managing habitat for this species in portions of its native range in which it is of conservation concern. Furthermore, the discovery that *O. bractella* can be taken by pheromone traps reveals that such traps may enable better monitoring of this species in its native range.

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### FIRST REPORT OF THE PALEARCTIC SPECIES *CYDIA CONIFERANA* (TORTRICIDAE) IN THE WESTERN UNITED STATES

A single adult male of *Cydia coniferana* (Saxsen, 1840) was collected in Tumwater, Thurston County, Washington State, in 2000. This moth was a non-target in a United States Department of Agriculture/Animal and Plant Health Inspection Service/Cooperative Agricultural Pest Survey (USDA/APHIS/CAPS) program aimed at detecting the European corn borer (ECB), *Ostrinia nubilalis* (Hübner). The collection method was a pheromone-trap baited with hybrid northern/southern strain ECB lure (1:1 Z11/E11-14Ac). This was the first record of *coniferana* recorded from North America since several adults were reared from the bark of red pine in New York (Schaffner 1959). The New York population apparently never established (W. Miller pers. comm.), although the species was listed from North America by Powell (1983).

*Cydia coniferana* is native to the Palearctic Region where it occurs throughout Europe east to Russia, China, and Mongolia. (Bradley *et al.* 1979; Zhang 1994). The larvae feed in the cambium layer of many coniferous trees, including *Pinus spp.*, *Picea spp.*, *Abies spp.* and *Larix sp.* (Bradley *et al.* 1979; Karsholt and Razowski 1996; Zhang 1994). Published information on larval feeding impacts is limited and variable. In England, where *coniferana* infestation is associated with fungal disease, it is not a significant pest (Bradley *et al.* 1979). Central European populations of *coniferana* are reported to enter the cambium only after the tree is wounded (Patočka and Turčáni 2005). However, Razowski (2003) reported

“occasional damage”, especially to pine nurseries, and *coniferana* is identified as a “harmful species” in western Russia (Medvedev 1987).

Adult *coniferana* are small (10–14 mm) dark moths (Fig. 1) with a wing pattern that is typical of many *Cydia* and *Grapholita* species (see Komai 1999; Razowski 2003). Recognition in sticky traps is difficult without genitalic dissection. Male moths can be identified by a short row of deciduous cornuti in the aedeagus and a ventral toothlike projection on the valves (Fig. 2) (Bradley *et al.* 1979). Some variation of adult morphology was noted in our samples. In particular, the white dorsal patch of the forewing is sometimes absent as noted by Razowski (2003). One feature of the male genitalia, the length of the ventral toothlike projection, was also variable. Descriptions or illustrations of the female genitalia (Bradley *et al.* 1979), pupa (Patočka and Turčáni 2005), and larva (Swatschek 1958) of *coniferana* have also been published.

In the summer of 2005, a preliminary pheromone trap delimiting survey for *coniferana* was conducted in western Washington from King County south to the Oregon border



FIG. 1. Adult males of *Cydia coniferana* in a pheromone trap showing variation in forewing pattern.

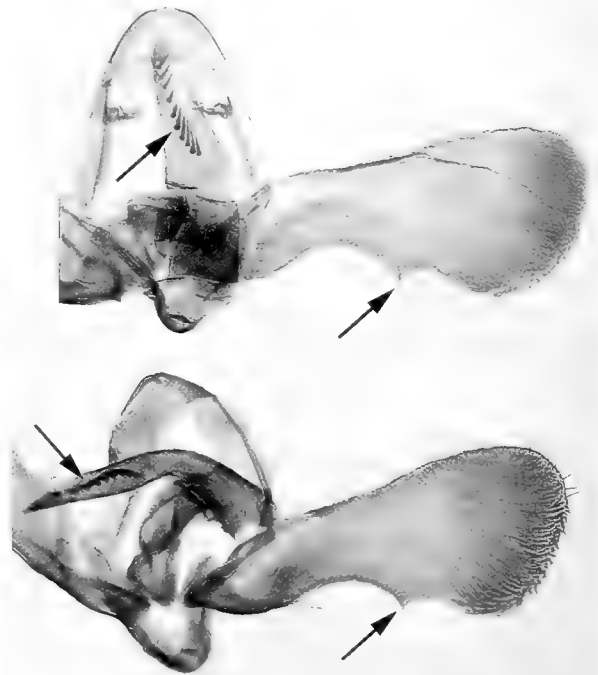


FIG. 2. *Cydia coniferana* male genitalia. Arrows point to the cornuti of the aedeagus and ventral toothlike projection of the valve. Note variation in length of the ventral tooth of valve.

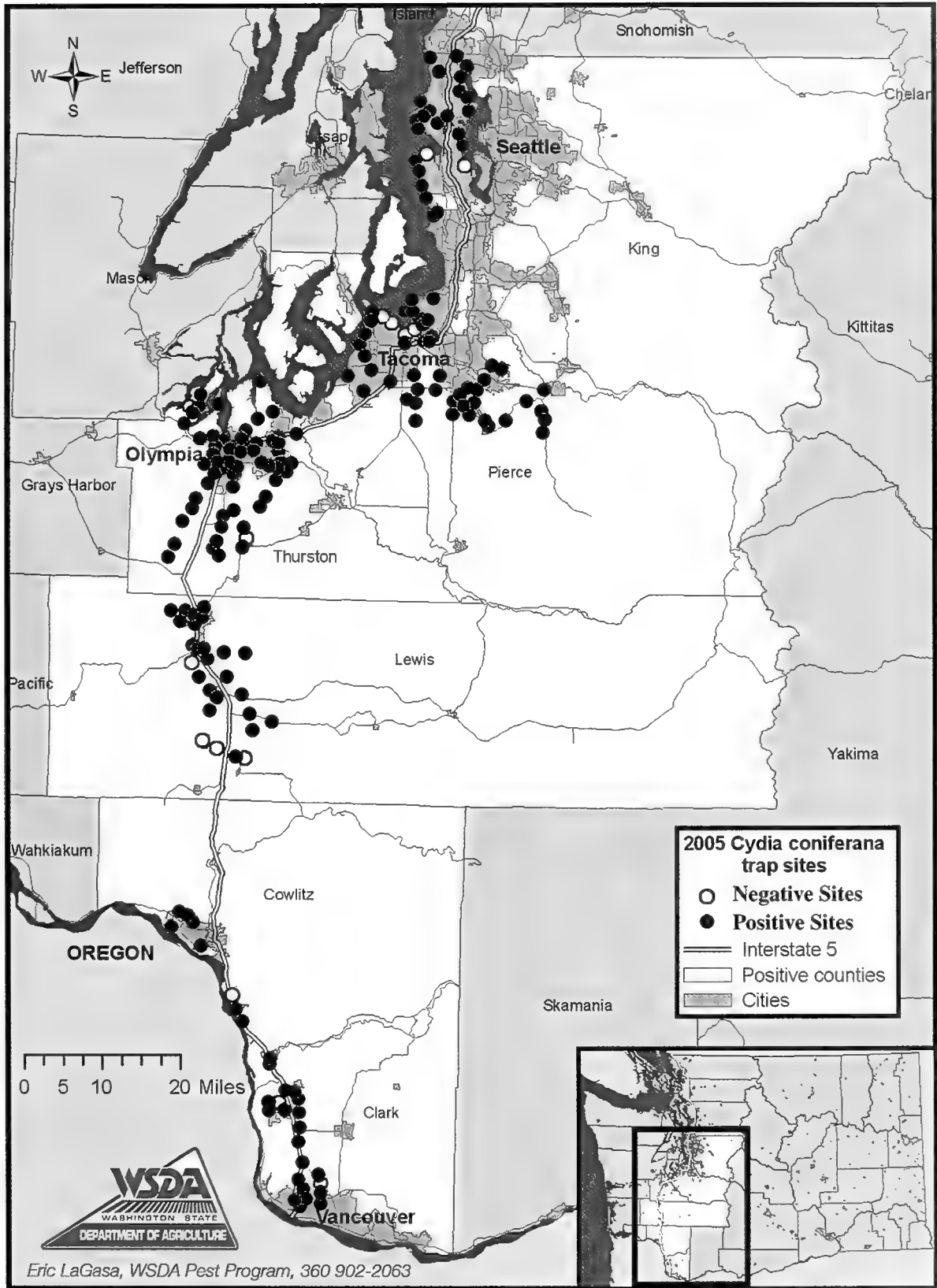


FIG. 3. *Cydia coniferana* collection sites in southwestern Washington State.

TABLE 1. 2005 *Cydia coniferana* trap site numbers and results by county.

County	Total Sites	Positive Sites	% Sites Positive	Total Moths	Average moths (per Pos. Site)
King	30	28	93.3%	885	31.6
Pierce	50	46	92.0%	976	21.2
Thurston	60	58	96.7%	1,453	25.1
Lewis	30	26	86.7%	400	15.4
Cowlitz	10	9	90.0%	154	17.1
Clark	20	18	90.0%	477	26.5
Totals	200	185	92.5%	4,345	23.5

(Fig. 3, also LaGasa and Welch 2005). Traps were placed in a total of 200 roadside or residential yard trees, mostly on *Pinus spp.*, *Abies spp.*, *Pseudotsuga menziesii*, and *Picea spp.* from early June until late August. Pherocon 2® type traps with lures consisting of 0.5 mg of E,8 – Dodecenyl Acetate on a hexane-rinsed red rubber septa were used. The lures were changed no later than every four weeks.

Survey results, summarized by county in Table 1, and illustrated in Figure 3, clearly show that *coniferana* is well established and widespread in the survey area. A total of 4,345 male *coniferana* were collected at 185 of 200 total sites, with an average catch of 24 per trap at positive sites. The average number of moths captured across counties surveyed was fairly uniform, and the distribution of positive sites and catch numbers did not vary substantially between rural/woodland areas and more urban sites. The majority of moths (80%) were captured during August with peak activity around the middle of the month. Additional monitoring is needed to determine the entire duration of adult activity and whether the species produces one or multiple generations in the Pacific Northwest.

Given the prevalent and uniform occurrence of *coniferana* in the surveyed area, it is likely that the current distribution of this moth includes more (if not all) of western Washington and possibly adjacent areas in Oregon and British Columbia west of the Cascade Mountains. Examination (including removal of bark) of potential host tree species in the area infested by *coniferana* revealed some evidence of larval damage matching the description given by Bradley *et al.* (1979), but no larvae were found. *C. coniferana* was found at numerous sites where *Pseudotsuga menziesii* (Douglas fir) was the only conifer present, suggesting that this species may be a potential host.

Voucher specimens collected in this 2005 survey are deposited at the United States National Museum (Washington, D.C.), the S. Passoa collection (Columbus, Ohio) and in the Washington State Department of Agriculture Insect Collection (Olympia, Washington).

Multiple introductions of microlepidoptera can occur on either coast of the United States (see Powell and Passoa

1991). Our data shows that a second introduction of *coniferana* established in the western United States. Regulatory entomologists only consider an organism to be introduced if there is evidence of an established breeding population (Pender 1983). Our data shows this is the case for *coniferana* which justifies inclusion of this species in the checklist of North American Lepidoptera.

We thank Dr. Wm. Miller (University of Minnesota, St. Paul) and Dr. J. Brown (Systematic Entomology Lab, Washington D.C.) for confirming the adult of *coniferana*, comments on the manuscript, and for valuable historical data. The USDA/APHIS/Otis Methods Development Center provided pheromone traps and lures. This survey was funded in part by a Cooperative Agricultural Pest Survey (CAPS) grant from the USDA APHIS Western Region (#05-8553-0737-CA).

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### POANES MELANE (HESPERIIDAE) OVIPOSITING ON AN AUSTRALIAN GRASS NATURALIZED IN CALIFORNIA

**Additional key words:** *Rytidosperma*, *Danthonia*, introduced species

The use of introduced plants as hosts by native California butterflies has been reviewed by Shapiro (2002) and Graves and Shapiro (2003), who found that the urban and suburban fauna of that state was now largely dependent on such plants. New records of this type appear regularly, demonstrating that butterflies colonize potential host plants more or less quickly after they appear in an area.

On 27 October 2006 I observed a female *Poanes melane* (W.H. Edwards) systematically searching for and ovipositing repeatedly on a low, tufted, apparently perennial grass I did not recognize in a parking strip in Berkeley, Alameda County, California. This grass was common in the neighborhood, occurring in lawns and waste ground in an older residential area of North Berkeley. Unable to identify it using Hickman (1993), I brought specimens to the U.C. Davis Herbarium where it was identified by Jean Shepard as *Rytidosperma racemosum* (R. Br.) Connor & Edgar (formerly placed in the genus *Danthonia*). This species was not recognized as naturalized in California when Hickman (1993) was in preparation. According to Stephen Darbyshire of Agriculture Canada, an authority on the genus, this grass was grown “experimentally” in gardens in Berkeley as early as 1941. It seems to have begun to spread in Alameda County in the early 1950s and is recorded as naturalized only in that county except for a 1978 record from the naval garrison on Angel Island, Marin County. According to Darbyshire and Barbara Ertter of the Jepson Herbarium at U.C. Berkeley as well as my own observations, it is now a fairly common weed in Berkeley and nearby Albany and will probably continue to spread.

*Rytidosperma racemosum* is originally from Australia. Various members of the genus were tested in California for forage potential as early as 1911 and *R. penicillatum* (Labill.), more commonly known as *Danthonia pilosa* R.Br., is naturalized in California, southern Oregon and Hawaii. It

ERIC LAGASA, *Pest Program, Plant Protection Division, Washington State Department of Agriculture, P.O. Box 42560, Olympia, Washington 98504-2560 USA*, email: elagasa@agr.wa.gov

STEVEN PASSOA, *USDA/APHIS/PPQ, The Ohio State University, Museum of Biological Diversity, 1315 Kinnear Road, Columbus, Ohio 43212 USA*, email: Steven.C.Passo@usda.gov

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would hardly be surprising to find *P. melane* and other native skippers using these plants elsewhere. Although the ability of *P. melane* to feed and develop successfully on *R. racemosum* has not been demonstrated, it accepts most perennial and some annual grasses in the laboratory. Scott (1986) lists five very diverse grasses in as many genera plus one sedge (Cyperaceae). He does not provide sources for these records. Garth & Tilden (1986) record two native perennial grasses in southern California. Various other records are scattered in the literature, none of them being on *Rytidosperma*, which as noted above was not even recognized as being part of the California flora! Bay Area populations are now “urbanized” and routinely breed on Bermuda Grass (*Cynodon dactylon* (L.) Pers., while inland California populations are confined to riparian-wildland habitats (Shapiro and Manolis, 2007).

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ARTHUR M. SHAPIRO, *Center for Population Biology, University of California, Davis, CA 95616*, email: amshapiro@ucdavis.edu.

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HANDBOOK OF ZOOLOGY, VOLUME IV, ARTHROPODA: INSECTA, edited by M. Fisher, Part 35 Lepidoptera, Moths and Butterflies, Volume 1: Evolution, Systematics, and Biogeography, edited by N. Kristensen, 1998, 490 pp, ISBN3-11-015704-7 and Volume 2: Morphology, Physiology and Development, edited by N. Kristensen, 2003, 564 pp, ISBN 3-11-016210-5, de Gruyter, Berlin and New York. List price (Amazon Books): Volume 1, US\$299.60; Volume 2, US\$347.20.

Few lepidopterists have the comprehensive knowledge or stamina to direct the production of *The Handbook of Zoology – Lepidoptera, Moths and butterflies*. Indeed, the two volumes that resulted from editor Kristensen's deliberate planning are more suitably described as 'encyclopedia' than 'handbook'. In 40 chapters written by outstanding contributors these books cover evolution, systematics, biogeography, comparative morphology and anatomy of early stage and adult Lepidoptera.

Volume 1: *Evolution, Systematics, and Biogeography* contains 21 chapters. The 'Historical Introduction' (Kristensen) enumerates critical landmarks marking the progress of Lepidoptera studies, and functioning as a gateway for further exploration. Chapter 2, 'Phylogeny and Palaeontology' (Kristensen & Skalski), is a lucid overview of superfamily-level relationships based on a deep understanding of the Lepidoptera groundplan, extant and fossil taxa. Figure 2.1 beautifully describes the groundplan, and should be of interest to all entomologists, and Fig. 2.2 gives a phylogeny for extant superfamilies of Lepidoptera. This chapter also lists known fossils by family; a useful reference guide to original studies. A chapter on 'Classification and Keys to Higher Taxa' (Carter & Kristensen) naturally follows. While the key to adults includes 46 superfamilies and does not require illustrations (readers will recognize all characters), the key to larvae is supplied with illustrations of basic larval morphology and leads to 129 categories, including superfamilies, families, and subfamilies. Chapters 4–19 cover higher groups; 'The Non-Glossatan Moths' (Kristensen), 'The Homoneurous Glossata' (Kristensen), 'The Monotrysian Heteroneura' (Davis), 'The Tineoidea and Gracillarioidea' (Davis & Robinson), 'The Yponomeutoidea' (Dugdale, Kristensen, Robinson & Scoble), 'The Galechioidea' (Hodges), 'The Zygaenoidea' (Epstein, Geertsema, Naumann & Tarmann), 'The Cossoid/Sesioid Assemblage' (Edwards, Gentili, Horak, Kristensen & Nielsen), 'The

Tortricoidea' (Horak), 'The smaller Microlepidoptera-Grade Superfamilies' (Dugdale, Kristensen, Robinson, Scoble), 'The Pyraloidea' (Munroe & Solis), 'The Axioidea and Calliduloidea' (Minet), 'The Butterflies: Hedyloidea, Hesperioidea, and Papilionoidea' (Ackery, de Jong & Vane-Wright), 'The Drepanoid/Geometroid Assemblage' (Minet & Scoble), 'The Bombycoidea and their relatives' (Lemaire & Minet), and 'The Noctuoidea' (Kitching & Rawlins). All these chapters have a standard format (likely owing to the editor's guidance), are well illustrated, and provide detailed accounts on classification and basic morphology of adults and early stages. No other book on Lepidoptera combines such a breadth of information and extensive citations. Although relationships between groups are discussed, chapters 4–19 do not include phylogenies. I found this a sensible editorial decision. Modern phylogenetic analyses are not homogeneously available for Lepidoptera groups, and discussions of conflicting hypotheses are better placed in the primary literature. Accordingly, chapters 4–19 rest on the solid ground of classical systematics and will remain lasting references for future generations. Chapters 20 and 21, 'Evolution of Larval Food Preferences in Lepidoptera' (Powell, Mitter & Farrell) and 'Biogeography of the Lepidoptera' (Holloway & Nielsen), are excellent reviews and should be required reading for general entomologists, and lepidopterists in particular.

Volume 2: *Morphology, Physiology, and Development* includes 19 chapters that cover all life stages. Here the chapters are slightly less homogeneous in format and coverage, and some are more thorough than others. Chapters 1 and 2 open the volume with detailed information about the 'Integument' (Chauvin & Kristensen) and 'Hairs and scales' (Kristensen & Simonsen). There one may learn, for example, that the relationship between scale size and wing length is not linear, and that several structures of the integument are still poorly understood. Chapter 3, 'Coloration: Patterns and Morphogenesis' (Nijhout) is a brief summary of classical and recent topics and covers both butterfly and moth color patterns. Chapters 4 and 5, 'Skeleton and muscles: adults' (Kristensen) and 'Skeleton and muscles: immatures' (Hasenfuss & Kristensen) make up one-fourth of volume 2, and these two chapters are not for the novice. They are a useful source of comparative information best appreciated by those who have wrestled with these topics for some years. Comprehensive descriptions of adult and larval muscles are provided together for the first time, and

furthermore, they attempt to standardize the terminology for many skeletal structures—something that is particularly timely for genitalic morphology. Chapters 6–9 and 16 concern the ‘Digestive and excretory systems’ (Barbehenn & Kristensen), ‘Respiratory system’ (Wasserthal), ‘Circulation and thermoregulation’ (Wasserthal), and ‘Nervous system’ (Yack & Homberg) and ‘Reproductive organs’ (Kristensen). These chapters remind me of R. Chapman’s original work *The insects: structure and function*. Although focused on Lepidoptera, these chapters are widely relevant to entomologists and provide up to date, detailed information and useful illustrations for early stages and adults. The chapters covering ‘Sensilla and proprioceptors’ (Hallberg, Hansson & Löfstedt), ‘Auditory and sound producing organs’ (Minet & Surlykke), and ‘Eyes and vision’ (Warrant, Kelber & Kristensen) provide a wealth of comparative detail that characterizes the two volumes of the *Handbook*: At risk of stating the obvious, it is extremely useful to be able to cross consult chapters. For example, Minet & Surlykke note that the forewing base tympanal organs are always innervated by a branch of the nerve IIN1c (p 289), which is illustrated by Yack & Homberg (p 234). Chapters 13–16 explore ‘Exocrine Glands: Chemical communication and chemical defense’ (Hallberg & Poppy), ‘Labial glands, silk and saliva’ (Akai, Hakim & Kristensen), ‘Endocrine glands and hormones’ (Sridhara, Bhaskaran & Dahm), and ‘Reproductive organs’ (Kristensen). These reviews encompass processes from the cellular to ecological levels, and point to huge gaps in our knowledge of certain glands. Finally, chapters 17–19 include ‘Karyology and sex determination’ (De Prins & Saitoh), ‘Eggs’ (Fehrenbach), and ‘Embryology’ (Kobayashi, Tanaka & Ando). These three chapters are framed in a broad, order-level comparative context and present valuable baseline information.

Perhaps the most important contribution of the *Handbook* is the scope of comparative information

conveyed in the two companion volumes. Readers can browse the chapters like the stacks in a library. This encourages scholarship by providing easy access to topics of direct or potential relevance to our research on Lepidoptera. The *Handbook* serves as a reminder that a holistic approach to research, including familiarity with embryology, host plants, wings, systematics, genitalia, sensilla, et cetera, will lead to a more sound interpretation of our data, whatever they are, and ultimately a deeper understanding of our study organisms. More than ever, academic biologists in the US face a demand for increased productivity through extramurally funded research. Although productivity is positive in principle, sacrificing quality for quantity, or depth for pace are not. The *Handbook* was done in the fine European tradition of bringing international contributors together with comprehensive excellence as the main goal. Some chapters combine many lifetimes of comparative research (e.g., ‘Skeleton and muscles’), and their production required dedicated work that can only be accomplished through scholarly maturity in the best sense of the word. Inasmuch as the mission of the Lepidopterists’ Society is to further our understanding of moths and butterflies in all aspects of their natural history and evolution, I feel that the *Handbook* is a giant step towards this goal. These two volumes will certainly stimulate us to dig deeper, look further, think laterally, and read more broadly. The cost of these books is prohibitive to students, but not beyond the reach of professionals. In closing I would like to say, Professors: share the *Handbook of Zoology – Lepidoptera, Moths and butterflies* with your students — they will not find such a wealth of information on the web.

CARLA M. PENZ, *Department of Biological Sciences, University of New Orleans, New Orleans LA 70148, USA. e-mail: cpenz@uno.edu.*

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Biology Department  
College of Charleston, 58 Coming Street,  
Charleston, South Carolina 29424-0011, USA  
scholtensb@cofc.edu

PEG TOLIVER, Layout Editor  
Natural Imprints  
706 Lake Road  
Eureka, Illinois 61530  
naturimp@mtco.com

PHIL DeVRIES, Book Review Editor  
Department of Biological Sciences  
University of New Orleans, 2000 Lakeshore Dr.  
New Orleans, Louisiana 70148-0001 USA  
pdevries@uno.edu

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